SCIENTIFIC AMERICAN

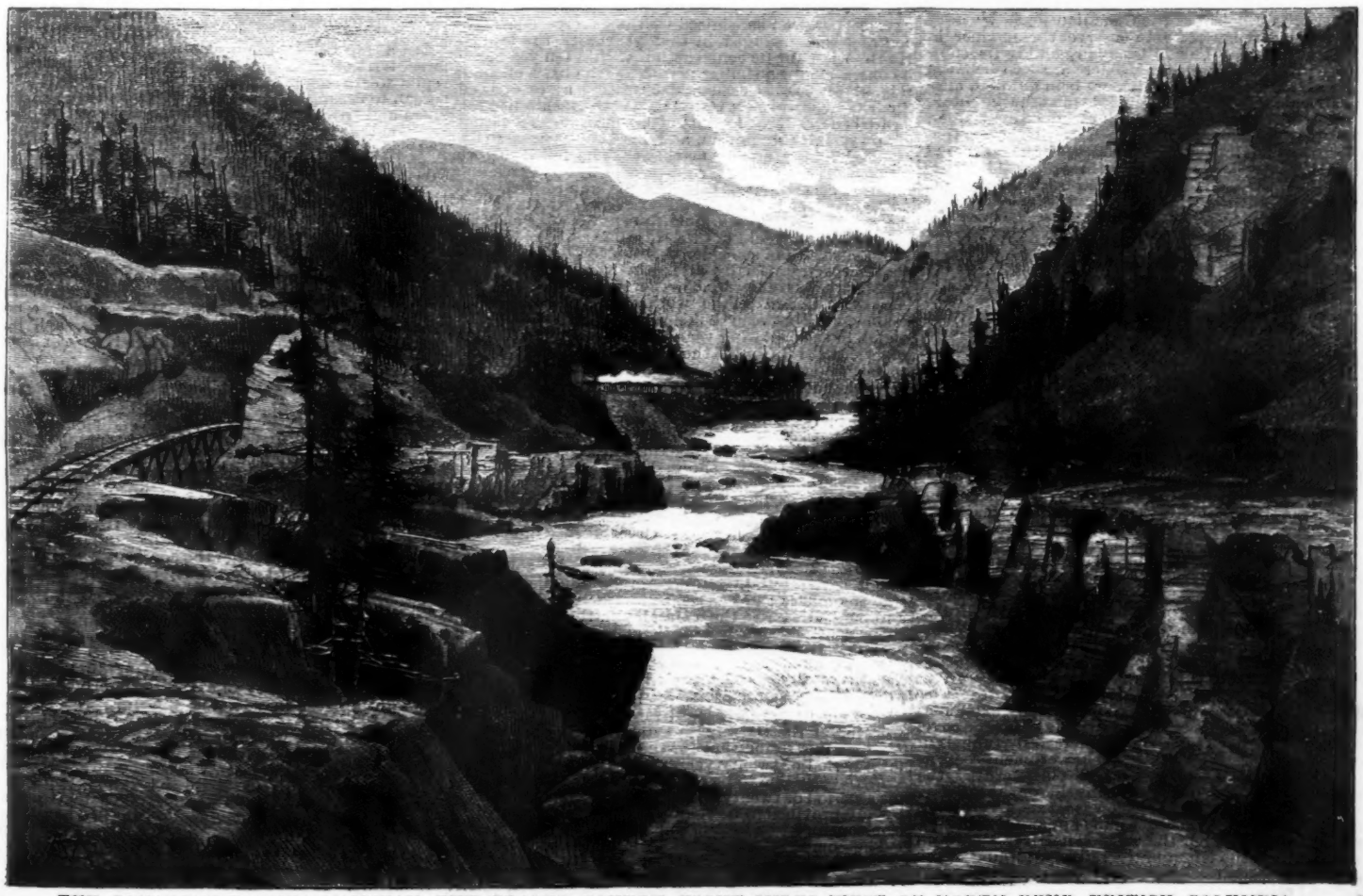
No. SUPPLEMENT, 684

Scientific American Supplement, Vol. XXVII., No. 684.
Scientific American, established 1845.

NEW YORK, FEBRUARY 9, 1889.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

THE CANADIAN PACIFIC RAILWAY—SNOW SHED AT ROSS PEAK, NEAR THE GLACIER HOUSE, BRITISH COLUMBIA.



THE CANADIAN PACIFIC RAILWAY—THE FRASER CANYON, EIGHT MILES WEST OF NORTH BEND, BRITISH COLUMBIA.

THE CANADIAN PACIFIC RAILWAY.

BRITISH COLUMBIA, a "land of the mountain and the flood," to which the Scottish Highlands are of tame and petty aspect, and which abounds more than Switzerland and Norway in wild and romantic scenery, furnishes the subjects of our special artist's sketches. This most westerly province of the Dominion of Canada, extending about eight hundred miles from north to south, and three hundred miles from east to west, from the Rocky Mountains to the Pacific seacoast, is intersected by several great mountan ranges; the Selkirk, the Gold Range, and the Cascade Range being the main interior groups, running generally from northwest to southeast, with frequent intervening spurs and offshoots. The Selkirk Range has quite an Alpine character, and forms the backbone of the country, rising often higher than the Rocky Mountains in this part of North America. The principal rivers, some of which at the beginning of their course flow northward, and turn afterward to the south, while others—the Kootenay, for instance—begin with a southward course and subsequently change to the northerly direction, form numerous lakes resembling the inland "lochs" of Scotland; but their channels are usually rock-bound, and their banks, except in the more open straths and valleys, where the land is very fertile, are overlooked by grand pine-covered mountains or cliffs and craggy peaks.

The Columbia River passes southward into the United States Territory of Washington, and issues between that Territory and Oregon, discharging itself into the Pacific Ocean. The Fraser River, which has its source in the Rocky Mountains, flows 650 miles, entirely within British Columbia, receiving the Thompson River at Lytton, and many other large streams, by which it is connected with the Kamloops, the Harrison, the Lillooet, and the Seton Lakes; the lower portion of the Fraser River from its mouth in the Gulf of Georgia, below New Westminster, is navigable by steamer for 90 miles up to the town of Yale.

Returning now to the Selkirk mountain range, which is crossed by the Canadian Pacific Railway, we must notice its highest summit, 11,000 ft. above the sea level, named after Sir Donald Smith, one of the chief promoters of this line. The passenger cannot fail to be struck by the view of Mount Sir Donald. It rises high above the southern verge of the Rogers Pass, close to a great glacier which, joining with another further south, form the head waters of the Illecillewaet River. This stream runs out from under the icy mass and over the bowlders and debris at the bottom of a deep gorge that crosses at right angles, though much below, the Rogers Pass. The glacier is a vast mass of ice fully a mile wide at the top, with the waters flowing out from underneath in several currents, uniting to form the river. In this gorge the company have built another pretty Swiss chalet for a stopping place, which they call the "Glacier Hotel," with magnificent mountain views. The railway avails itself of this ravine, and of another that comes into it at right angles a short distance below, to get down out of the pass. The line, by repeated double loops, runs for six miles, descends 600 feet, and accomplishes just two miles of actual distance. Here is an achievement of engineering that took a railway genius to conceive and execute. First, the line runs southward, along the side of the gorge toward the glacier, then it crosses a high bridge and curves back on the other side, coming out near where it started, but at a much lower level. Next, it curves round into the second ravine, swings across it, and comes back again at 120 ft. lower level, yet only 130 ft. further down the pass. Then it doubles upon itself, and crosses the river, immediately recrossing again. Here are six almost parallel lines in full view, each at a lower stage, and each made up largely of huge trestle bridges. These are the "loops" of the Canadian Pacific.

It is not less remarkable to observe the manner in which the Canadian Pacific Company builds its snow sheds to protect the railroad. There are two between the summit and the hotel which are being united, altogether over a mile long. On the side next the mountain the shed is of strong crib work, built of cedar timber, 10 by 12 inches, laid two inches apart, with cross timbers dovetailed into the two sides of the crib and spiked together with seven-eighth spikes 16 inches long. This crib is 35 feet high, and filled with stone. On the other side timbers of the same size and about five feet apart are spiked upon the massive mud sills and cross sills. Upon the cross sills heavy lean-to supports are mortised into the upright timbers and into the sills, all spiked together. Across the top is a floor of two-inch planks, braced from the center, and another sloping roof of the same thickness, slanting down nearly to the ground on the lower side of the track, completes the shed. The whole roof is as strong as a bridge. In some parts of the line there are double tracks—one within the shed for winter use, the other outside, to be used during the summer months. Every kind of work on the road seems to be done without regard to cost, but with the determination to make it as perfect as a single-track road can be. The station houses are, or are to be, all ornamental.

Startling as is the passage through the Rocky Mountain and Selkirk ranges, the carving out of the line upon the steep banks of the deep and winding canyons of the Thompson and Fraser Rivers has also called for great engineering skill, and gives for hundreds of miles a succession of magnificent scenes. The hotel at North Bend is a good stopping place for tourists who wish to see more of the Fraser canyon than is possible from the trains. At Boston Bar, a few miles below North Bend, the principal canyon of the Fraser commences, and from here to Yale, twenty-three miles, the scenery is intensely interesting. It has been described as "ferocious." The great river is forced between vertical walls of black rock, where, repeatedly thrown back upon itself by opposing cliffs, or broken by ponderous masses of fallen rock, it madly foams and roars. The railway is cut into the cliffs 200 feet above, and the jutting spurs of rock are pierced by tunnels in close succession. At Spuzzum the government road, as if seeking company in this awful place, crosses the chasm by a suspension bridge to the side of the railway, and keeps with it, above or below, to Yale. Ten miles below Spuzzum the enormous cliffs apparently shut together and seem to bar the way. The river makes an abrupt turn to the left, and the railway, turning to the right, disappears in a long tunnel, emerging into daylight and rejoining the river at Yale.—*Illustrated London News.*

THE CANADIAN PACIFIC RAILWAY.*

By THOMAS C. KEEFER, President Am. Soc. C. E.

IN selecting the subject for my address, I have chosen the "Canadian Pacific Railway," the most recent and the most extensive enterprise in a country which, in railway mileage per capita, is second only to the United States. It is not only the most important road in Canada, but it has characteristics which distinguish it from many other railways.

First.—It connects the Atlantic with the Pacific Ocean under one ownership, and upon the shortest American route between Europe and Asia.

Second.—As the single transcontinental line for a country nearly as large as the United States, it possesses the largest area tributary to it of any of the trunk lines.

Third.—No other transcontinental road is so lightly burdened with interest-bearing securities. The whole charge upon 2,500 miles of road is $35,000,000 five per cent. mortgage bonds, $14,000 bonds per mile, or $700 per mile per annum.

Fourth.—As the most recent overland road, it possesses the most modern equipment and the smallest scrap heap.

When the mainland provinces of Eastern Canada (all of which, except the great lake-indented one, Ontario, bordered on Atlantic tide water) became united, in 1867, as the Dominion of Canada, the federal government took steps to acquire the vast territories between the Rocky Mountains and the watershed of Lake Superior, over which the Hudson's Bay Company exercised jurisdiction—and in which they claimed ownership. Canada refused to recognize the company as possessing anything more than the right to trade in Rupert's Land, the watershed of Hudson's Bay, and invoked the aid of the imperial government. The company was disposed of by a cash payment of $1,500,000, the retention of their occupied posts, and five per cent. of all lands lying between the Red River Valley on the east and the Rocky Mountains on the west, and extending as far north as the Great Saskatchewan, which may be surveyed into townships before the year 1920. Over 70,000,000 of acres have already been surveyed, the company's share of which is 3,500,000 acres, out of which they have sold 470,000. The company pays for the survey of their lands at the rate of eight cents per acre.

This purchase carried the Dominion of Canada to a line marked by the summit of the Rocky Mountains—between the 49th and the 54th parallel, thence on the 120th meridian to the 60th parallel—which lines form the eastern boundary of the Pacific province, British Columbia. The 60th parallel is the northern boundary of British Columbia, north of which the Dominion was extended westward to the 141st meridian west of Greenwich, which is the eastern boundary of Alaska in that latitude. This was one of the largest real estate transactions on record.

In 1871, British Columbia entered the union, thus extending the Dominion of Canada to the Pacific Ocean. The principal condition of this union was that the Dominion should, within ten years, connect, by rail, the seaboard of British Columbia with the railway system of Canada, construction to commence at the Pacific coast in 1873. Surveys were immediately commenced and prosecuted for about nine years, but the work of construction was not begun until 1875, and then not at the Pacific coast, but at the Lake Superior end. Work was not commenced at the coast until 1879. Some of the delay is accounted for by the fact that the records of the first three years' surveys were destroyed by fire in Ottawa early in 1874.

The Parliament of Canada had decided in 1872 that the road should be constructed and operated by a private corporation subsidized by the government, and a contract was arranged in that year with the late Sir Hugh Allan for its construction within ten years, and its operation for a similar period, on the basis of a subsidy of $30,000,000 cash and 50,000,000 acres of land. Sir Hugh controlled a transatlantic steamship line and desired the railway for inland connection. This excited powerful antagonism, and his project was so discredited in the money market that he failed to form his company. The government also was defeated on a question arising out of this contract, and retired. The new government was bound to carry out the agreement with British Columbia, but not feeling responsible for its details did not regard time as the essence of the contract, and considered it an impossible one in that respect, especially after the failure of Sir Hugh Allan. It was determined, therefore, in 1874, to proceed with it as a public work, and construction was commenced between Lake Superior and the prairie region in the following year. The government of 1874 was defeated in 1878, their opponents returning to power, who after continuing the construction as a public work until 1880, reverted to their original policy of construction by a private company. The terms of the contract with the present company were:

First.—$25,000,000 cash and 25,000,000 acres of selected lands in the fertile belt, in addition to the right of way for track and stations, shops, docks and wharves, on or through public property.

Second.—Free import of all steel rails and fastenings, fence and bridge material in wood or iron for original construction, and telegraph wire and instruments for first equipment.

Third.—The government sections under contract—about seven hundred miles—to be completed, with stations and water service, but without rolling stock, and handed over to the company on the completion of their contract as a free gift. (The cost of these has exceeded $30,000,000.)

Fourth.—Perpetual exemption from taxation by the federal government or by any province to be created by it, as well as by any municipal corporation of the latter, on all property used for the construction and working of the railway and upon their capital stock. Also similar exemption for the company's land grant for a period of twenty years, unless sold or occupied.

Fifth.—No line to be chartered south of the railway for a period of twenty years, either by the Dominion or by any province to be created by it, except for a direction southwest or west of southwest.

The company contracted to build about 2,000 miles of railway, and to work the transcontinental line for ten years after completion, the standard to be that of the Union Pacific Railway as it was in 1873. Liberal as the terms agreed upon appear, the sequel proved that they were none too much so. The capital stock was fixed at $100,000,000, and it was expected that land sales, or the security of the land grant, would make up any additional amount required and enable the company to complete the road without mortgaging it. The lands could not be sold while government lands alongside them were being given away; and land grant bonds, although received at par for company's lands, could not for the same reason be negotiated to any considerable extent. In the autumn of 1883, $65,000,000 of the capital stock had been sold, and nearly all the proceeds expended in construction. The road was assailed at home and abroad by opponents of the government and by rival interests, and such distrust created that the remainder of the stock could not be sold to realize the amount necessary to complete the work in hand. The company then decided to support their stock by purchasing from the Dominion government a guarantee of three per cent. per annum for ten years, for the $65,000,000 of stock already sold, making similar provision for the $35,000,000 unsold. The cost of this terminable annuity was $16,091,152 calculated at four per cent., to meet twenty semi-annual payments of one and a half per cent. each. Of this amount $8,710,240 was paid in cash and security was given for the early payment of the remainder, but the success of this bold financial policy was defeated by the effect on the money market at this time of the crisis which occurred in the affairs of the Northern Pacific Railway. The stock, with the government guarantee for so short a term of years, could not be sold at an adequate price, and the company, early in 1884, was obliged to apply to the Dominion government for a loan of $22,500,000. This amount, added to the balance due upon the annuity purchase, made a total loan of $29,880,000, to secure which the government took a lien upon the entire property of the company.

In order to obtain feeders and distributors for the transcontinental line, the company had commenced the construction and acquisition of a railway system in Ontario and Quebec, and branch lines in Manitoba, with a total mileage as great as their contract line, their entire interest in which was transferred to the government, as well as their unsold stock and their land grant, as security for this loan.

In consideration of this loan, the company agreed to complete the transcontinental line by May 1, 1886, five years in advance of the time fixed by the contract.

Railway construction at the rate of nearly five hundred miles per annum rapidly exhausted the loan, and the first lien of the government over all their property effectually barred the sale of their stock. They found it necessary, therefore, in 1885, to ask that the $35,000,000 of unsold stock in the hands of the government be canceled, and an equal amount of five per cent. first mortgage bonds be issued and held by the government as security for the loan, the mortgage to cover the same security as the loan. The thirty millions loan was payable May 1, 1891, with four per cent. interest. The government agreed to accept $20,000,000 of the first mortgage bonds as security for so much of this debt, and the security of the whole unsold lands of the company (over 20,000,000 acres) for the balance of $9,980,000. Of the $15,000,000 bonds remaining, the company deposited with the government $8,000,000 as security for a temporary loan of $5,000,000, and negotiated the remainder, paying back the temporary loan within a few months, and thus releasing $8,000,000 of bonds.

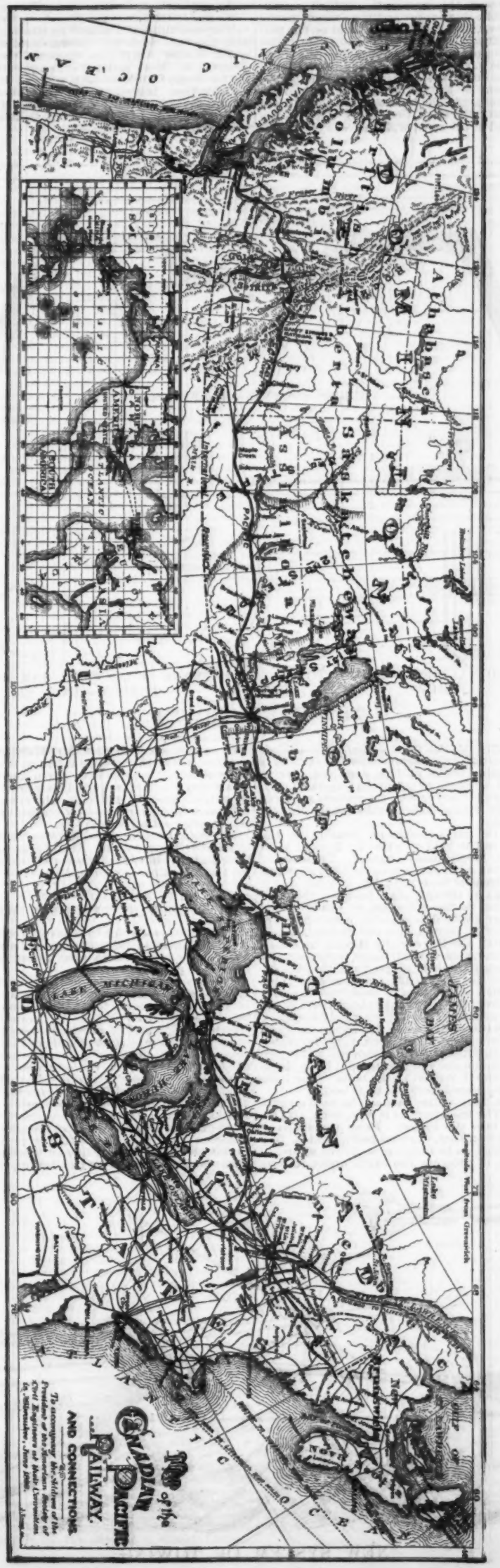
Events took a turn favorable to the company at last in 1885. The road had been so far completed, that early in that year, and while navigation was closed on the great lakes, a military expedition was sent around the north shore of Lake Superior, where there never had been a trail before, to put down rebellion in the northwest territories. In November of that year the last spike was driven in British Columbia on a track laid from ocean to ocean. Moreover, the opposition of stock jobbers and rivals subsided when it was seen that the government of Canada was determined to sustain the railway at all hazards. Politically, the existence of the government depended upon its completion, but the higher consideration was, that the expenditure was so vast and ramified, and the liabilities incurred so great, that suspension would have produced a financial crisis such as Canada had never seen, and one which it was the duty of any government, if possible, to avert.

In March, 1886, the company proposed to pay off their indebtedness to the government, returning all the cash advanced upon the $20,000,000 bonds, and surrendering 6,793,014 acres of land at $1.50 per acre, for the balance. The government accepted this, and being satisfied that no security was required for continuous operation, surrendered the $5,000,000 land grant bonds held as security for that purpose, but retained $1,000,000 of these to enforce a change of route at Mount Stephen, in the Rockies, where a temporary line of nine miles was adopted to save time and money in opening the road, and upon which there is a grade of 4½ per cent., or double that permitted by the contract.

The year 1887 saw the company freed from its indebtedness to the government, and in uncontrolled possession of its property. For the first time since incorporation no legislation for its benefit was required; but in the present year the government has found it necessary to obtain the surrender of the company's monopoly as to charters west of Lake Superior, the object of which was to protect their line north of that lake. To effect this, the government guarantee to pay interest for fifty years on an issue of $15,000,000 three and a half per cent. bonds, secured upon the unsold portion of the company's land grant—about 15,000,000 acres. The government becomes a trustee and guarantees the interest for half a century; but not the principal, unless and until placed in funds for that purpose by the company. The proceeds of land sales are to be funded with the government, which is to pay three and a half per cent. on any excess of the amount necessary to pay interest upon, or to redeem, the bonds.

The Canadian Pacific Railway is the work of Canada exclusively. The road was undertaken by Canada, as a political and commercial one, to fulfill the compact with British Columbia, and unite together all the provinces of the confederacy, but chiefly in order to develop the vast estate purchased from the Hudson's Bay Company. It has been carried out by her people without any assistance from the imperial government—not

* Address at the annual convention of the American Society of Civil Engineers, at Milwaukee, Wisconsin, June 28, 1888.—*From the Transactions of the Society.*



even the indorsement of Canadian securities to obtain money at lowest rates, as was done in the case of the loans raised by Canada for the construction of the St. Lawrence canals, and for the Intercolonial Railway. Its importance to the empire has, however, been recently acknowledged by the British government, which unites with Canada in subsidizing a line of mail steamers between Vancouver and the British possessions at Hong Kong.

My apology for the space given to the financial history of this railway is my belief that engineers will wish to know how (as well as why) it has been constructed through a wilderness, and, as compared with some of its predecessors, in so short a time. This result is due to the great financial ability and the still greater courage of its only president, and to the great administrative ability and tireless energy of the vice-president and general manager, who has had full control of construction and the freest scope in carrying out his plans. Upon the president was imposed the arduous and anxious duty of raising a greater sum than that provided by the government; upon the vice-president, the equally arduous duty and responsibility of expending both those sums.

LOCATION.

The general location of the route from ocean navigation at Montreal to the Rocky Mountains, on Canadian territory, is governed by three natural features—Lake Superior, the Lake of the Woods, and Lake Winnipeg. It must go north of the first two and south of the third. Passing from the Ottawa Valley into that of Lake Huron, the line, on its way thence to Lake Superior, traverses for about one hundred miles the watershed of Hudson's Bay near the height of land. In descending thence to Lake Superior, numerous long rock cuts are encountered, separated by shallow valleys, generally with marshy bottoms having little material for road bed over them or near them except solid rock, bowlders, and hard pan. Timber of the required dimensions being abundant, the grade was thrown up, shortening the bottom line and reducing the depth of the rock cuts, and trestling was freely resorted to. The embankments have been greatly increased, and much of the rock cutting has been wasted, but it is claimed that from difficulties of position and cost of supplies, the final cost will not exceed that of a slower mode of construction; and, from the local scarcity of bank material, the filling in can be done cheaper by train. The greater extent of embankment thus obtained has a special value in this district, which has the greatest snow fall, with the exception of the Selkirk Mountains, of any portion of the route. Along the eastern shore of Lake Superior, high, rocky bluffs are encountered, and heavy rock cuts and numerous tunnels are necessary. The rock excavation runs up to hundreds of thousands of yards on some miles; the cost of one mile is said to approach $700,000.

The highest summit reached between Montreal and Lake Superior is 1,550 feet above tide, or about 950 feet above Lake Superior, and the highest between Lake Superior and Red River is about 1,560 feet above tide.

The maximum grade in either direction between Montreal and Lake Superior is one per cent., and the minimum curvature 6 degrees. Between Lake Superior and the Rocky Mountains, the maximum grade going west is, with one exception, one per cent. The exception is a short grade starting from Medicine Hat, a divisional station, where a pusher is always at hand. Coming east, the maximum is 40 feet as far as Winnipeg on the Red River, thence to Lake Superior, 26 feet. This last is the section constructed by the government.

There is an interesting example of rail creeping on a highly elastic road bed on this division, where the line crosses a "muskeg"—the Indian term for bog—causing it to yield about 6 inches to every passing train. With a heavy consolidation engine, hauling 35 cars, this track crept 26 inches in the direction in which the train was moving. The rails creep for about three-quarters of a mile east and about half a mile west of a small bridge at the foot of a grade in both directions. They creep with every train, and in warm weather will often run 12 inches under an ordinary train. Track bolts break almost daily, and repairs are to the extent of a box of bolts per month.

Cinder ballast keeps the track in line and surface fairly well, but does not in the least prevent the creeping of the rails. Lining and surfacing are necessary at least once a week. On account of the flanges on the angle plates, spikes must be left out of a tie on each side of these plates, otherwise the creeping rails would carry the ties with them, and throw the track out of gauge. Three trains running in the same direction are often sufficient to open all joints on one side and close them on the other side of the bridge between. The whole muskeg, when a train is passing, shows a series of short waves 5 to 6 inches deep, rising and falling with the passing load, and the rails can be seen moving with the passing train.

The general superintendent of the western division, Mr. Whyte, to whom I am indebted for the above, proposes to use 12-foot ties, 40-inch angle bars, and cut a slot in alternate sides of the rail at every tie, as a means of holding the rails in position.

During the construction of this portion of the railway, two rather serious questions arose out of the interpretation of specifications. The first was upon the work done under the government, west of Lake Superior; the second upon the work done by the company east of that lake. The government specification for rock read: "All stones and bowlders measuring more than 27 cubic feet to be measured as solid rock;" "all large stones and bowlders measuring less than 27 cubic feet, and all loose rock, whether *in situ* or otherwise, that may be removed with facility by hand, pick, or bar, without the necessity of blasting, to be measured as loose rock." The resident engineers returned as loose rock "large stones and bowlders" removed without blasting, but the contractors protested. The question turned on the minimum size of large stones and bowlders. Only "large" stones could be counted as loose rock, but there was not this repetition of the word in the case of bowlders. The court decided that stones or bowlders which were handled and not shoveled were loose rock. Perhaps the words "may be removed with facility by hand," which, as placed and punctuated, apply as well to the stones and bowlders as to the ledge rock, influenced the decision.

In the other case, the company had appointed a successful contractor as manager of construction, with

plenary powers. The standard government specification was changed by limiting loose rock to stones and bowlders between 1 and 27 cubic feet, and by a special classification for solid rock, the result of the manager's experience. Some formations of the country rock were known to be harder than others, and, no doubt, with a view to get a better average, separate prices were taken for granite (the rock of the country), for mica schist, and for trap rock. For this last two prices were taken, one for trap in cuttings under and another in those over three feet in depth.

Separate prices were also taken for hard pan and cemented material, but tenderers generally did not recognize any difference in their bids, no doubt because the specification applied the same test for both. It read: "Hard material, where a good picker cannot keep more than two good shovelers going, shall be termed hard pan, or cemented material, as the case may be." The price for hard pan and cemented material was eighty cents—more than double the earth price; the good picker and the two good shovelers could not be expected to be always together; and however numerous the former might be at any time or place, the "pickings" were good, whether the pickers were so or not.

As to solid rock classification, the results on one division were surprising. The geology of the route, which consists largely of metamorphic rocks, was "altered" decidedly. Trap under three feet was $3.40 per yard, while granite was $2.20, and more trap was returned at this price than could have existed had all the cuttings been floored with it. When trains could get through, the company's chief officers found their ballast trains working in cuts where there was no ledge rock, but in which large amounts, including trap, had been returned. They ordered a remeasurement, which was confirmed by another one made by the court; and on one contract the final estimate was reduced between three and four hundred thousand dollars. Other similar cases on this division were settled on the basis of the remeasurement. The section engineers who measured and classified the work in the first instance were generally in accord with the remeasurement, and the sub-contractors were settled with on their classification. After the sub-contractors had been paid off, a revised classification was made out for the final estimate, in which the formation was altered, as effectually as by an igneous eruption, granite merging into mica slate, and trap overflowing everywhere.

The Prairie Section.—The government had located their line from the Red River to the Rocky Mountains in a northwesterly direction, in order to strike the Yellow Head or Leather Pass, by which route grades of one per cent. were attainable. This direction was also a central one for the largest area of the fertile belt; but it encountered rather formidable crossings of the two Saskatchewans and their tributaries. The Red River crossing is about latitude 50 degrees, and the Pacific terminus but little north of the international boundary (latitude 49 degrees), while the Yellow Head Pass is in latitude 53 degrees. The route from Yellow Head Pass to the Pacific terminus was necessarily circuitous, and the distance from the Red River to Kamloops* by this pass was 1,350 miles.

The result of the government surveys showed that the Yellow Head Pass was the most southern practicable one for a line limited to one per cent. grades, and as it was an excellent one in this respect, and was also in the direction of the best line for a colonization road through the prairies, it was adopted. The contract specified this pass, but left the company their own choice of route to reach it. The question of future competition by parallel lines on the prairies was not considered while it was a government road. Such lines, so far as they opened up new country, would have been encouraged by the government within reasonable limits. But with a private corporation the case was different; it could not afford to take the risks which a government might safely do. The general direction of their road was nearly due west, and as they were on the 50th parallel at the Red River, they decided to abandon the government location, and follow that parallel as closely as possible, but to shorten the through distance and to leave no room for a competing trunk line to the south of them. Possibly, also, climatic considerations, in a latitude where every degree counts, supported this deviation. This line traverses the best of the wheat country for nearly 400 miles west of Winnipeg, and the best stock raising and mining districts, within 200 miles of the mountains. Between these there lies the only section where there is any scarcity of water. Experimental farms have established that there is sufficient rain for crops, and the chief inconvenience to the company at present is the want of wells for tank supply to the road. Surface reservoirs are proposed to secure these.

In the prairie sections precautions have been taken against snow blockades by keeping the line in embankment wherever possible, and by widening, and flattening the slopes of necessary cuts, and depositing the spoil well off, as a snow screen. At stations, sidings are thrown out so far that cars standing on them cannot cause drifts on the main line. Only twelve miles of snow fencing are used on the prairie section. There was no detention from snow last winter, between the Columbia River and Lake Superior, exceeding four hours at any one time.

There is no good gravel in large quantities for 400 miles west of Winnipeg, but pockets were found sufficient to ballast the wettest portion of the road. The road bed is crowned off, and top prairie soil is used for surfacing, which gives a smooth running track for moderately heavy traffic, and one which it is expected will last at least five years.

(To be continued.)

THE A. J. HARTFORD STEEL RAILWAY TIE.

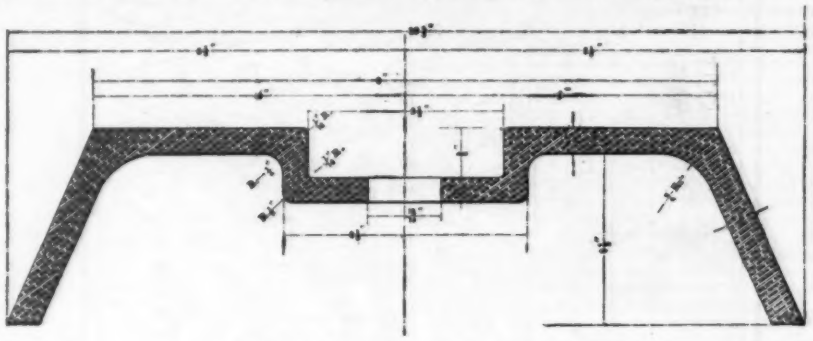
AMONG the many metallic railway ties which have been brought out during the last few years, we doubt if there is any which has as much practical merit as the one we illustrate herewith. (The engravings are reduced to just half size.) It is the invention of Mr. A. J. Hartford, of New York City, and is the result of years of experience in railroad work and personal inspection of metallic ties under many different climates and conditions. Its construction will be readily understood from the cuts. It is rolled from soft steel 5-16 in. thick in the body and ¾ in. thick in the flanges.

It will be seen from the cross section, which is given in half size, that the side flanges and the channel in the center give stiffness, and also by their hold on the ballast prevent shifting lengthwise of the track. The curve of the ends prevents shifting laterally. Evidently this form of tie has more lateral stability than the wooden tie, for in order to shift it, not only must the ballast at one end of the tie be moved, but also the whole prism of ballast in the hollow of the tie. It will be noticed that the Hartford tie is very thick in the throat of the bend at the ends, which gives a maximum amount of strength at the points where it is needed. The mere thickening of the metal under the rails, as is done in some other forms of ties, does not give as much additional strength as might be supposed, as a metal tie—a bridge in itself—needs its greatest strength where the bridge strain comes, rather than directly under the weight.

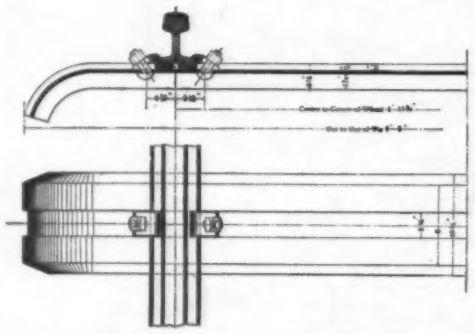
The Hartford tie has a maximum bearing on the ballast, and the rail is held in place by hooked clips which lie in the longitudinal channel. These are of such width that the rail has a bearing of the full width of tie, 8 in. The bases of these clips are mitered, and it is designed to have enough play between them to allow for variation in the thickness or width of the rail flanges. They are held in place by bolts which are bent at an angle of 45 degrees with the vertical. These bolts are made with the Harvey grip thread, by means of which the nut, when turned home, automatically presses the threads into such shape that they constitute an effectual nut lock. The clips receive these bolts in slots, which allow them to be shifted in or out some ¾ in. or more. By this contrivance there is ample provision for adjusting the rail accurately to gauge, whatever may be the variation of the flange in width or thickness. This feature has been very favorably passed upon by leading railroad engineers, and it permits a rail to be taken out and another put in by slacking the nuts without removing the bolts. The bolts can also be put in place before the tie is laid.

With these ties, 22 in. splice bars can be used on supported joints. The Hartford tie is 90 in. long, and extends down 6 in. into the ballast. From the shape of this tie it will be seen that, once properly bedded, very little work will need to be done on it in the nature of tamping, etc., as it protects the earth under it from the weather. It also has a maximum of holding strength with which to keep a track in position, and will prevent the spreading and creeping of rails.

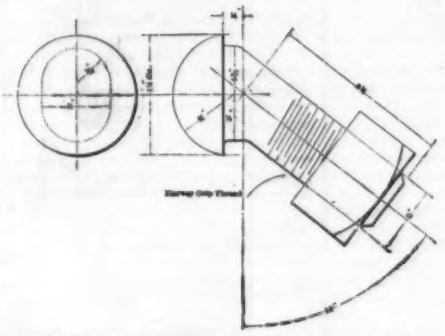
We understand that the New York Central Railroad will lay one third of a mile of its Hudson River division with this tie. Such well known engineering authority as Mr. Walter Katte has expressed the utmost confidence in it. Most railroad men agree that the time is not far distant when wooden ties will be supplanted by metallic ties. Indeed, it is probable that there is economy in the use of such a tie as the Hartford at the present time, and the New York Central's experiment will be watched with interest.



CROSS SECTION—HALF SIZE.



LONGITUDINAL SECTION AND TOP VIEW.



TRACK BOLT WITH HARVEY GRIP THREAD—HALF SIZE

THE HARTFORD TIE.

In connection with this, Mr. Hartford asserts that the first cost of the steel tie need not stand in the way of its adoption, as where any given number of renewals of wooden ties are required, one-third the number of steel ties wisely distributed will answer the purpose fully as well, and this proportion can be kept up until the transformation is complete.

The A. J. Hartford Steel Railway Tie Manufacturing Company, Temple Court, New York, has been organized, and will have facilities for manufacturing 12,000,000 ties annually.—*Railway Review.*

NEW SYSTEM OF TOWING.

FREIGHT vessels, for the purpose of reducing to as great a degree as possible the net cost of the goods carried, are arranged in such a way as to operate as rapidly as possible.

Hatches of wide dimensions, maneuvered by pulleys, give access to their capacious holds, and steam windlasses and shears serve for the unloading, which is often facilitated by steam or hydraulic cranes which may be set up on the wharf at which the vessel lands. On another hand, any of these steamers may meet upon its route another ship, which has become disabled and needs to be towed. A cable carried by a rowboat to the ship in distress is made fast to the latter, and then there begins a difficult voyage for the vessel that has consented to do the towing, since it is submitted to shocks from the waves, which interfere with its sailing, often damage its machinery, and sometimes even cause collisions that it is impossible to prevent, the vessel towed acting somewhat like an inert body, and all at once coming up close to the towing vessel in conse-

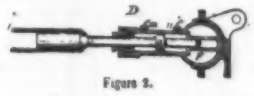
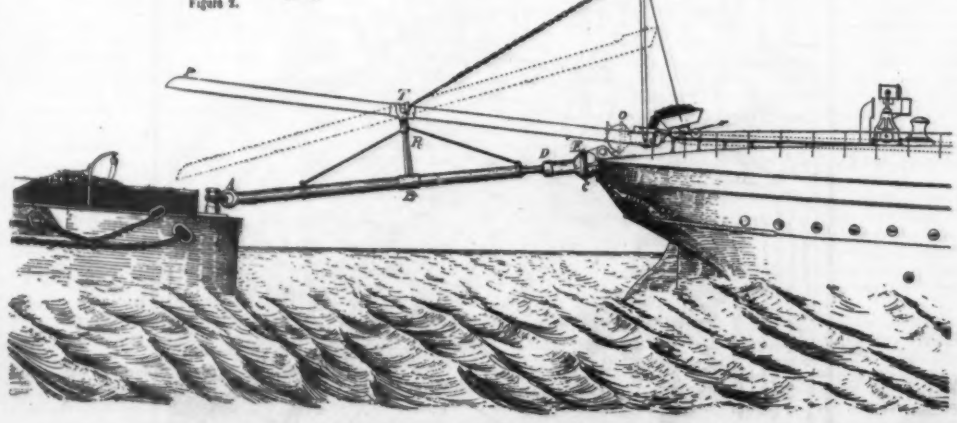


Figure 2.



NEW SYSTEM OF TOWING.

* 258 miles from Pacific coast, and where all lines meet.

quence of the combined motions of the tow line and the waves.

Often, too, when the sea becomes rough, the ungovernable motions communicated to the two vessels cause a breakage of the cable, and the operation has to be resumed with more difficulties and more dangers.

Finally, a steamship may chance to be at sea with empty bunkers, and be under the necessity of reloading at the expense of another ship which has consented to stop in order to supply it with a portion of its own fuel; and then begins a very delicate operation, that of a transshipment at sea, which can be effected only with the entire stoppage of the two vessels, as complete a calm as possible, and with precautions that necessitate the attention of each in order to prevent accidents of every kind.

The apparatus herewith represented inaugurates a new system of towing which is destined to render great service to vessels of all kinds. It was devised by Vice-Admiral Albini. Our engraving represents two ships, one towing the other by means of the new apparatus, which consists of a rod, A B C, of sufficient length to allow it to be placed upon the quarter deck of a ship, that is to say, it may be 25 or 30 ft. in length. It might, moreover, be made in sections that could be screwed together when needed for use.

This rod is fixed to the stern of the ship by means of a strong joint, which permits of the entire affair being turned back upon the deck when the towing is finished. The joint is provided with a spherical cavity, C, in which is held the head, E (likewise spherical), of a cylinder with which the rod, A B C, is connected. This connection is made by means of the piston, H (Fig. 2), cast in a piece with the end of the rod, A B C, and moving in the interior of the cylinder, H.

This piston is in equilibrium under the influence of two equal pressures of air furnished by the conduits, *m n*, connected with an air pump on board the towing vessel.

At the other extremity, the rod terminates in a ring that permits the towed ship to connect the rod firmly with one of her anchor posts. Such being the case, when a ship consents to do towing, it approaches the ship to be towed as near as possible and lets fall upon it the rod, A B C, after the fashion of a grapnel. The ring, being seized by the sailors, is made fast, and the towing begins at once, without damage, strain, or shock. In fact, the shocks are transmitted from one vessel to the other by means of the action of the piston, H, upon the pressures of air that are exerted upon its surfaces, after the manner of springs whose elasticity can be regulated.

Besides, the joint, E, through its mobility, permits of all the relative motions of the two ships without restraint, and the towage is rendered safe and easy, and frees the captain of the towing vessel of a large amount of care and responsibility.

After the connection has been made, a transshipment from one vessel to the other may be easily effected, either simply and in an absolutely dead calm, by means of a simple plank fixed upon the rod for the passage of sailors carrying bags of coal, or by means of a process devised by Vice-Admiral Albini, and shown in the engraving. The apparatus consists of a long cylindrical conduit, P O, provided with a hopper, S. This conduit is provided with trunnions resting upon the bearings of a rod, R, fixed upon the towing rod by means of two tension bars, and held vertically by the cable, T.

The fuel is carried to the hopper by means of cars. Then this extremity is lifted by another pulley, so as to cause the conduit, P O, to tilt. The load then slides and reaches the other ship. The chute is then lowered again and the operation of loading proceeds without the two ships having to stop or to be concerned about the state of the sea.

After the loading is finished, if the towed vessel has no further need of aid, it detaches itself from the ring of the rod, A B C, which is then lifted, pulled backward, and laid upon the deck of the towing vessel, which latter then pursues her course. It may be seen that this apparatus can even be used upon wharves for the loading and unloading of vessels.—*Chronique Industrielle.*

PROGRESS OF OUR NEW NAVY.

THE year 1889 will be an important one in the history of the new navy of the United States. The trials and experiments of the great cruisers Baltimore, Chicago, and Charleston, to say nothing of the gunboat Yorktown and the dynamite cruiser Vesuvius, will keep the public at large more cognizant of the developments in the naval establishment than did the announcement in the year past regarding the progress of the work on these new vessels.

During the year 1888 the great shipbuilding yards of Cramp & Son, at Philadelphia, the Union Iron Works, of San Francisco, and the Columbia Iron Works, of Baltimore, have been rushing to completion the work of construction on the war vessels in their charge. On April 28 the Cramps successfully launched the dynamite cruiser Vesuvius and the gunboat Yorktown. On the last Thursday in July the Charleston was slipped from the ways of the Union Iron Works, and in September following the powerful cruiser Baltimore was added to the list of vessels launched by the Cramps of Philadelphia. In the government yards, at Norfolk and Brooklyn, the work of construction has been, with a few exceptions, uninterrupted on the new battle ships Texas and Maine, and in those private yards throughout the country where contracts for war vessels have been awarded, the work is being rapidly pushed ahead.

The association of old wooden craft and battered hulks with all pertaining to our navy has been so common with a large class of people that to them the rapid changes made of late in the type of vessels and style of armament are wholly incomprehensible. That the navy of the United States is making rapid strides toward the front rank of armed forces on the sea is undeniable, and if Congress will but exhibit the same spirit of liberality shown in its appropriations of the last four sessions, the supremacy of the navy will result in a comparatively short space of time.

With all great nations having seaports and maritime trade it is the custom to maintain a fleet of war vessels, not only for home defense, but for the protection of interests abroad. These war vessels they constantly increase in efficiency or replace with others more in conformity with the developments of the day, until now huge ironclads fly the ensigns of Great Britain, France, Germany, Russia, and Austria all over the world. But with us little or nothing has even been attempted in the line of improvement up to within the last few years. We stood at the head of the naval forces of the world at the close of the civil war, and our muster rolls showed a complement of 100,000 men enlisted in the service and for duty afloat. The war over, our naval force was reduced to a minimum, and many of the vessels then in service exist to the present day. Our wooden ships of both the navy and the merchant marine have been noted the world over for the beauty of their lines and general appearance, and previous to the advent of the new navy the arrival of an American corvette in the midst of a fleet of foreign ironclads was the occasion always of unrestrained admiration.

Notwithstanding the efficiency shown by our navy in the past few years on such occasions as the bombardment of the Corean ports, the protection of Americans at Alexandria, the clearing of the Isthmus of Panama of the rebel Preston's army, and the numerous timely arrivals for the protection of Americans during periodical outbreaks in South America, our navy officers have constantly felt their inability to cope with difficulties likely to arise at any moment, especially with the vessels they have in the past commanded. Instead of using the money required to rebuild and refit an old vessel, officers have urged that this money be put into a new vessel—a vessel of a type compatible with the times, and capable in every respect to fight on equal terms with the many foreign ironclads now afloat. As it is, Congress has so far complied that when the cost of repairs on a vessel exceeds twenty per cent. of the original building cost, the vessel is to be condemned and sold. Under these regulations resulted the sale of the Tennessee, Shenandoah, and Lackawanna.

We have the personnel, the brain, the talent. We have the guns. What we need are the vessels, and Congress is now rushing to completion a class of cruisers which, when finished, will stand a favorable comparison with any of a like class in the world. Before speaking of the war vessels in the navy, it is proper to give in tabulated form the list of vessels in the navy of the old type, the station of each at the end of the year 1888, and the number of guns carried. The majority of these guns are smooth-bore Dahlgrens, with one 8-in. rifle pivot, and a breechloading Parrott, 32-pounder or 80-pounder, and a complement of Gatling guns and Hotchkiss revolving cannon.

Name.	Commander.	Station.	Guns.	Tons Displacement.
Trenton	Capt. N. H. Farquhar.	Flagship Pacific.	10	3,900
Lancaster	Capt. T. F. Kane.	Flagship European.	10	3,250
Pensacola	Capt. A. R. Yates.	Flagship No. Atlantic.	16	3,000
Hartford			14	2,900
Brooklyn	Capt. Byron Wilson.	Mare Island Navy Yard.	14	3,000
Richmond	Capt. A. V. Reed.	En route to So. Atlantic.	14	2,700
Omaha	Capt. F. V. McNair.	China.	12	2,400
Vandalia	Capt. C. M. Schoonmaker	Pacific.	8	2,100

The vessels are unarmored cruisers and "second rates" in tonnage.

UNARMORED CRUISERS—THIRD RATE.

Name.	Commander.	Station.	Guns.	Tons Displacement.
Juniata	Comdr. W. C. Wise.	En route to New York.	8	1,900
Galena	Comdr. G. W. Sumner.	No. Atlantic.	8	1,900
Swatara	Comdr. J. McGowan.	So. Atlantic.	8	1,900
Ossipee	Comdr. A. G. Kellogg.	No. Atlantic.	8	1,900
Quinnebaug	Comdr. C. H. Davis.	European.	8	1,900
Mohican	Comdr. J. B. Coghlan.	Pacific.	8	1,900
Iroquois		Mare Island Navy Yard.	7	1,575
Kearsarge	Comdr. A. P. Brown.	En route to So. Atlantic.	7	1,550
Adams	Comdr. R. P. Leary.	Pacific.	6	1,375
Alliance	Comdr. G. W. Pigman.	So. Atlantic.	6	1,375
Essex	Comdr. T. F. Jewell.	China.	6	1,375
Enterprise	Comdr. B. H. McCalla.	European.	6	1,375
Nipsic	Comdr. D. W. Mullan.	Pacific.	6	1,375
Monocacy	Lieut.-Comdr. Gilpatrick	China; ordered sold.		
Tallapoosa	Comdr. F. W. Dickens.	So. Atlantic.	6	1,270
Thetis	Lieutenant-Comdr. W. H. Emory.	Alaska.	2	1,250
Intrepid		Not in commission.		1,150
Alert	Comdr. J. G. Green.	Pacific.	4	1,020
Ranger	Comdr. F. A. Cook.	Pacific.	1	1,020
Yantic	Comdr. O. F. Heyeman.	No. Atlantic.	4	900

MONITORS—THIRD RATE.

Name.	Condition.	Guns.	Tons Displacement.
Puritan	Repairing.	4	6,000
Monadnock	Repairing.	4	3,818
Amphitrite	Repairing.	4	3,815
Miantonomoh	Repairing.	4	3,815
Terror	Repairing.	4	3,815
Ajax	In ordinary.	2	2,100
Canonicus	In ordinary.	2	2,100
Mahopac	In ordinary.	2	2,100
Manhattan	In ordinary.	2	2,100
Wyandotte	In ordinary.	2	2,100
Comanche	In ordinary.	2	1,875
Jason	In ordinary.	2	1,875
Catskill	In ordinary.	2	1,875
Lehigh	In ordinary.	2	1,875
Montauk	In ordinary.	2	1,875
Nahant	In ordinary.	2	1,875
Nantucket	In ordinary.	2	1,875
Passaic	Naval Academy.	2	1,875

The Alarm in the following list is armored (torpedo craft).

UNARMORED CRUISERS—FOURTH RATE.

Name.	Commander.	Duty.	Guns.	Tons Displacement.
Alarm	In ordinary.		1	800
Michigan	Comdr. H. F. Picking.	Great Lakes.	4	835
Despatch	Lieut. W. S. Cowles.	Special duty.	2	500
Pinta	Lieut.-Comdr. J. S. Newell	Pacific.	4	550
Palos	Lieut.-Comdr. J. E. Craig.	China.	7	430

In the foregoing lists of naval vessels mention has been made only of those capable of active duty. To be sure, there is a host of wooden sailing vessels serving out the remainder of their days at some navy yard, or used as schoolships for apprentices and kindred purposes. Among them may be mentioned the Constellation, Constitution, New Hampshire, Dale, Portsmouth, Jamestown, Saratoga, Independence, Vermont, St. Mary's, Wabash, Franklin, and Minnesota. For cruising purposes, duty as police, deep-sea sounding and surveying, commercial development, and strategic and tactical instruction, the navy is divided into five squadrons, the North Atlantic, the Pacific, the Asiatic (commonly called China station), the European (extending as far south on the west coast of Africa as St. Paul de Loando), and the South Atlantic, the latter including Madagascar and the west coast of Africa as far north as St. Paul de Loando.

Since the advent of Secretary Whitney to the navy department, an impetus has been lent to the construction and building up of the new navy. The secretary offered $15,000 for the best plan of an armored cruiser that should be submitted to a board of officers at the navy department. The prize was to be given irrespective of the nationality of the competitors. The result was that many foreign naval architects sent in plans and designs and competed with our own naval constructors. Special prizes were also offered for particular designs, notably that for an armored cruiser of 6,000 tons displacement and an armored battle ship of the same displacement.

The plans submitted for these two vessels came from English, French, and American designers. It may seem strange that we sought designs and plans from foreign sources, but the Secretary had in view the gaining of all the information possible, no matter what the origin, then apply a little of our own inventive genius, and thus turn out a vessel of the finest and most serviceable type. English shipbuilders construct war vessels for different nations throughout the world. Why not, then, obtain information from these same shipbuilders, and, if possible, apply it to our new vessels? This has been the spirit which has actuated the officials at the navy department in the building up of the new navy.

The following table gives the list of the unarmored vessels of the new navy:

Name.	Condition	Guns.	Tonnage.	H. P. or Speed.
Dolphin	In com'n.	1 6-in. rifle.	1,485	2,240
Boston	In com'n.	2 8-in. rifle. 6 6-in. rifle.	3,189	3,780
Atlanta	In com'n.	2 8-in. rifle. 6 6-in. rifle.	3,189	3,350
Chicago	In com'n.	4 8-in. rifle. 8 6-in. rifle.		
Charleston	Launched	2 5-in. rifle. 2 8-in. rifle. 6 6-in. rifle.	4,500	5,084
Baltimore	Launched	4 8-in. B. L. R. 6 6-in. B. L. R.	3,730	7,000
Yorktown	Launched	6 6-in. B. L. R.	4,413	9,000
Petrel	Launched	4 6-in. B. L. R.	1,700	3,000
Newark	Building.	12 6-in. B. L. R.	860	1,100
Philadelphia	Building.	12 6-in. B. L. R.	4,083	8,500
San Francisco	Building.	12 6-in. B. L. R.	4,324	19 knots.
Concord	Building	6 6-in. B. L. R.	4,083	19 knots.
Bennington	Building.	6 6-in. B. L. R.	1,700	3,400
Vesuvius	Launched	3 15-in. dynamite guns.	1,700	3,400
First class torpedo boat	Building.	8 automobile torpedoes.	725	20 knots.
Cruiser No. 6			99	23 knots.
Cruisers Nos. 7 and 8			5,300	20 knots.
Cruisers Nos. 9 and 10			3,000	19 knots.
Practice vessel			2,000	Speed not fixed.
			800	

In the list of armored vessels for the new navy we have the following:

ARMORED VESSELS.

Name.	Condition.	Guns.	Speed.	Tonnage.
Maine	Building.	4 10-in. B. L. R. 6 6-in. B. L. R.	9,000	6,648
Texas	Building.	2 12-in. B. L. R. 6 6-in. B. L. R.	8,000	6,300
Coast defense	Plans ready.	1 16-in. 115-ton B. L. R. 1 12-in. 48-ton B. L. R. 1 15-in. dynamite gun.	5,400	4,000
Puritan	Completed in hull.	4 10-in. B. L. R.	3,058	6,060
Terror	Completed in hull.	4 10-in. B. L. R.	838	3,815
Miantonomoh	Completed in hull.	4 10-in. B. L. R.	1,080	3,815
Amphitrite	Completed in hull.	4 10-in. B. L. R.	1,000	3,815
Monadnock	Completed in hull.	4 10-in. B. L. R.	3,000	3,815
Armor'd cruiser	Not commenced			7,300

To compare the vessels of the new navy, as given in the above, with those of other countries, it may be interesting to know that of the 19-knot war ships of 3,000 tons and upward, Great Britain has 10; the United States, 8; France, 5; Spain, 3; Japan, 2; and Russia, 1. In this summary the position of the United States is second, and, considering the short growth of the new navy, the above standard is very high.

The importance of unarmored cruisers and high speed can be judged from the remarks of Secretary Whitney in his last annual report. The Secretary says:

"The importance which has been placed upon this branch of naval armament will be appreciated from the statement that England and France possess sixty-five vessels of the class known as unarmored cruisers. . . . We cannot at present protect our coast, but we can return blow for blow, for we shall soon be in a condition to launch a fleet of large and fast cruisers against the commerce of an enemy, able to inflict the most serious and lasting injury thereon. The one characteristic which an unarmored cruiser must possess is great speed. She must be able to escape from ironclads and outrun, so as to overhaul, merchantmen. If slower than ironclads she could not keep the sea, and if slower than merchantmen she might as well stay in port."

During the past year, the fastest, largest, and most powerful protected cruisers yet laid down are the

Blake and Blenheim of the English service. The displacement of these vessels is 9,000 tons each; the indicated horse power 20,000; trial speed 22 knots, with a continuous sea speed of 20 knots. These vessels have heavy protective decks, ranging from four to six inches in maximum thickness. The Piemonte, of the Italian navy, is the fastest cruiser built during the year just passed. Sir William Armstrong & Co. were the builders, and she was bought from the Armstrongs by the Italians. Her displacement is about 2,500 tons, and it is expected, with her 12,000 horse power, that she will develop a speed of 21½ knots.

Of the new vessels for the American navy which have been under trial, none has developed such remarkable speed as the dynamite cruiser Vesuvius, now undergoing a series of trials before a board of United States naval officers. The Vesuvius has developed a rate of speed equivalent to 21·47 knots per hour, and what with the terrible destructive powers possessed by her three 16-inch dynamite guns she will be one of the most formidable vessels in the navy.

The introduction of dynamite guns into the naval service was not without considerable opposition on the part of many navy officers, the prejudice against the use of dynamite in warfare being openly avowed. This prejudice has for the most part been overcome, and many officers have learned to look favorably on this dynamite cruiser, which is likely to create as much wonder in the naval world as did the Monitor and her appearance in 1862.

The advance in the type of guns has been one of the most marked features of our naval development. The guns now in course of construction for the new vessels are the designs of an ordnance board composed of navy officers. These guns have attained remarkable success, and the velocity obtained compares favorably with the best results of those of Armstrong's and Krupp's build. The principal developments during the year in the department of ordnance have been in improved powder and projectiles. The greatest improvement in the manufacture of gunpowder has been made in France and Germany, whereby, in the case of the former, initial velocities of 2,400 and 2,600 foot seconds have been obtained. Such an increase in velocity increases the energy of the projectile. In the case of our new six-inch breech-loading rifles a projectile could be driven through fifteen and one-half inches of iron if propelled by this description of powder. As it is, a projectile from the six-inch breech-loading rifle, when propelled by the regulation American powder, pierces twelve inches of iron. Experiments are in process to obtain a higher grade of powder, and when found, the efficiency of our guns will be proportionally increased by its use.—*N. Y. Times.*

AUTOMATIC REGISTERING DYNAMOMETER.

THE accompanying illustrations show an automatic registering dynamometer in which some fluid is used for indicating the amount of power passing through the apparatus. The dynamometer consists of two pulleys, F and L, F keyed to a horizontal shaft, while L runs loose on the same shaft. On the arms of the fast pulley, F, are fixed two small cylinders, C C, shown in Figs. 3 and 6. The arms of these cylinders are arranged in such a manner that they come in contact with the arms of the loose pulley, L (Fig. 2). The loose pulley, L, is driven by a belt from the fly wheel or the pulley of the machine to be tested, while round the fast pulley, F, a brake strap is arranged as shown in Fig. 6. The power from the machine is therefore transmitted by means of the arms of the loose pulley to the water or other fluid contained in the cylinders, C, which communicate through small pipes, H, with a passage, A, in the horizontal shaft (Figs. 2 and 6). A is connected by a small pipe, J, to an ordinary pressure gauge, G (Fig. 1), which registers the pressure exerted on the fluid in the cylinders, C. On the end of the horizontal shaft, and forming part of the coupling for the pipe, J, is fixed a worm, X, which gears with a small index wheel or revolution counter, W. On the boss of this index wheel is fixed a small cylinder, B, round which passes an indicating card, K. On the spindle of the pressure gauge, G, is fixed a small pinion which gears with the rack, R, to the end of which a pencil is attached. This pencil is in contact with the indicating card, and as this card travels at the same rate as the index wheel, a diagram of the pressures and the traversed distance is obtained. If it be desired to test machines or shafting, the brake strap is removed, and the machine or shafting under operation is driven from the fast pulley, F, while the loose pulley, L, is actuated from the engine or countershaft from which the machine or shafting is usually driven. Fig. 5 shows the arrangement for using long indicating cards for extended trials. The barrel, B, is attached to the boss of the index wheel, and the paper, which is coiled on a drum, is kept in contact with B by a small loose cylinder. The pulley shown dotted in Fig. 2 is sometimes used instead of the pulley, F, for greater convenience when testing machines or shafting. The advantages claimed by the inventor for this dynamometer are that in testing an engine the indications are not obtained direct from the brake strap, and also that the indications are free from the friction arising from the moving parts of the dynamometer.—*Industries.*

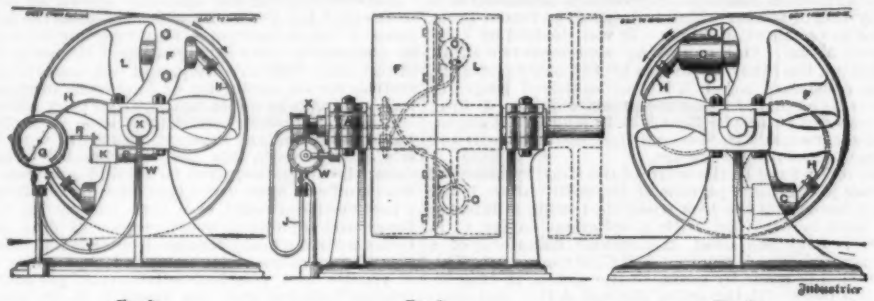


FIG. 1. FIG. 2. FIG. 3.

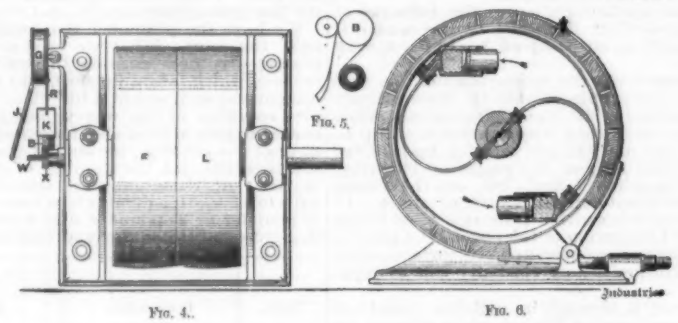


FIG. 4. FIG. 5. FIG. 6.

AUTOMATIC REGISTERING DYNAMOMETER.

THE COMPRESSED AIR COMPANY OF PARIS.

DURING the summer of 1888, the members of the Society of Civil Engineers were invited to visit the establishment of the Parisian Compressed Air Company. We were among the number of the visitors. The visit was of great interest to the manufacturers, mechanicians, and electricians who were present. In fact, we had before our eyes a specimen of a factory installation that permitted of producing the power of 3,000 horses.

The compressed air is employed during the course of the day in three very distinct services: (1) During the day time, in the distribution of motive power to manufacturers; (2) in the evening, for the production of electricity for lighting; and, during the twenty-four hours, for the actuating of pneumatic clocks.

It was for the distribution of the motive power necessary for the driving of a clock that the compressed air service was begun in Paris, in 1881. By reason of the difficulties that the erection of works in the center of Paris would have met with, with their large number of steam engines, compressors, and air reservoirs, they were installed near the confines of the city territory, on the heights of Belleville. They very rapidly increased, and now occupy an area of 107,500 square feet, two-fifths of which are covered with buildings. Fig. 1 gives a plan view of the whole.

Consequent upon some experiments made upon the high pressure conduits that connect the works of Saint Fargeau Street with the horary centers, a second grant of 40 years, starting from Aug. 1, 1886, was accorded by

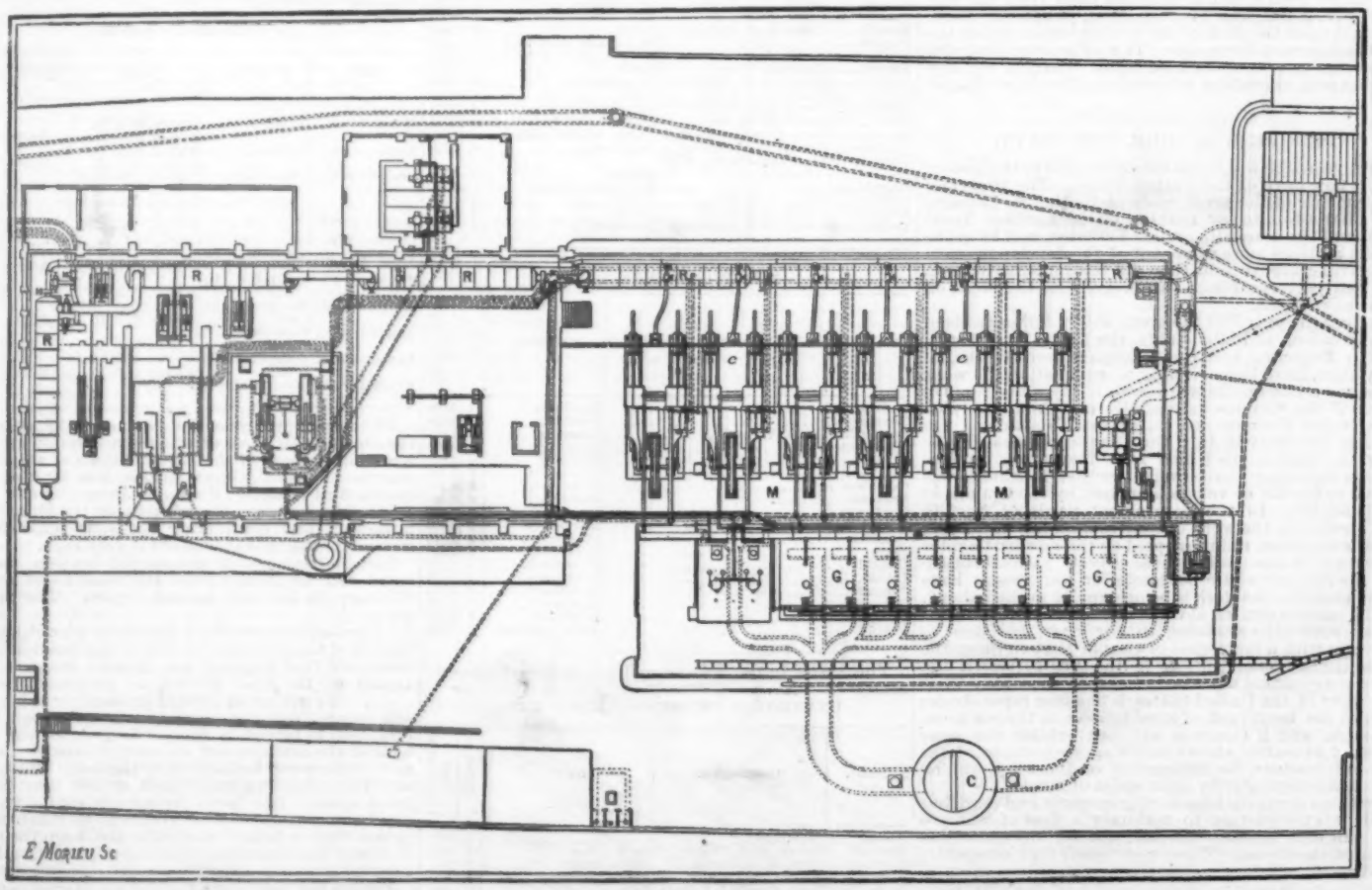


FIG. 1.—PLAN VIEW OF COMPRESSED AIR WORKS.

the municipal council to the Parisian company, and this gave it the right to lay and preserve a line of pipes for the distribution of compressed air, designed for household and all industrial uses.

There is a certain retrospective interest in recalling the principal clauses of the contract. The city of Paris pledges itself to deliver no similar authorization for the first five years. Coal, oil, and other materials employed are to be exempt from all city dues.

The city is not to interfere in the private service of the exploitation, but reserves to itself, nevertheless, 30 per cent. of the net profits, that is to say, calculated after deductions made (1) of all costs of exploitation and superintendence, (2) of 5 per cent. for the reserve fund, (3) of 10 per cent. for the amortizement of the capital, and (4) of 6 per cent. interest to serve for the capital stock.

The installation of the new works was begun in February, 1887. They are contiguous to the old ones built in 1881, and which produce a power of 600 horses. The new part produces 2,400, and both together, then, produce 3,000 h. p. Fig. 2 gives a perspective view of the engine room, and Fig. 3 of the boiler room. The engines for compressing air are 10 in number—2 horizontal 120 h. p. Corliss engines actuating, through belting, 8 Sautter-Lemonnier compressors; 2 vertical, coupled Casse engines, with walking beam, directly actuating 2 Casse compressors of a total power of 300 horses; and 6 compound Paxman engines of 350 h. p. each.

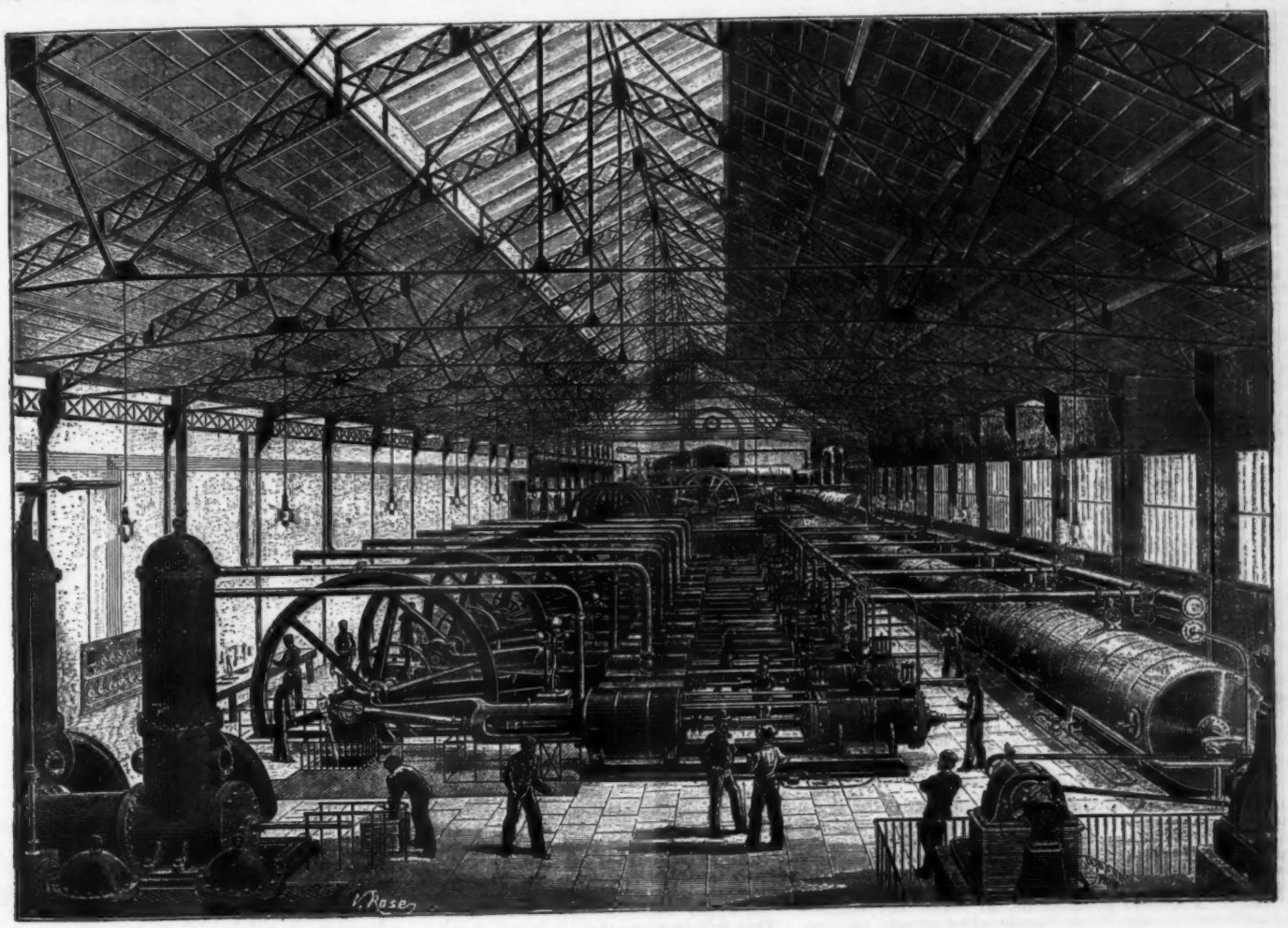


FIG. 2.—ENGINE ROOM.

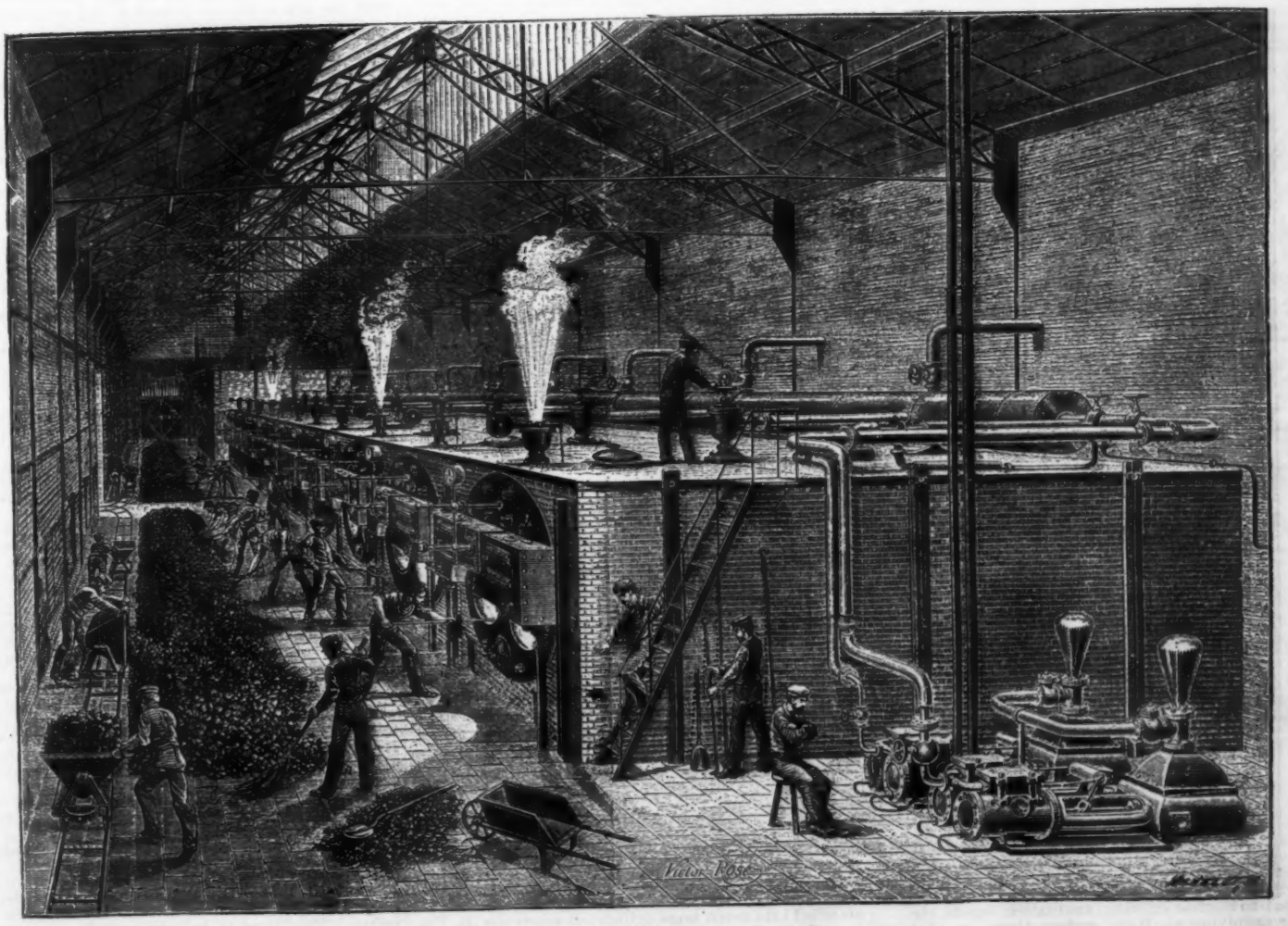


FIG. 3.—THE BOILER ROOM.

In these latter motors, the distribution to the small cylinder is effected through the intermedium of three plates; one fixed, another moved by an eccentric, and the third by a slide connected with the governor.

The piston of each cylinder is connected directly with a Blanchod compressor. Through this mode of connection, the benefit of the work accomplished by the steam upon the face of the piston is greater. The engines are provided with a revolution counter, which is connected electrically with a general registering apparatus. The works contain 22 compressors—8 Sautter-Lemonnier compressors, in which the air is cooled through the intermedium of a water cistern into which the piston plunges; 2 Casse compressors, in which the cooling is effected through the injection of a spray of water; and 12 Blanchod compressors, in which the cooling is effected through water introduced by suction.

The suction valves of these apparatus are formed by the cylinder heads. All these compressor apparatus united take from the atmosphere more than seventeen million cubic feet of air per day, in order to distribute it in Paris under pressure in the form of motive power, applied to electric lighting, ventilation, hoists, etc.

For supplying all these motors, there are 13 steam generators distributed in two masses of masonry. The first comprises 9 semi-tubular Paxman boilers, with double furnace and double return flame, each boiler having a heating surface of 1,290 square feet. In the same masonry support there are 2 semi-tubular Mennier boilers, each having a heating surface of 910 square feet. The smoke from these 11 generators is drawn into the atmosphere through a chimney 130 feet in height, having an internal diameter of 18 feet at the base and 10 at the top.

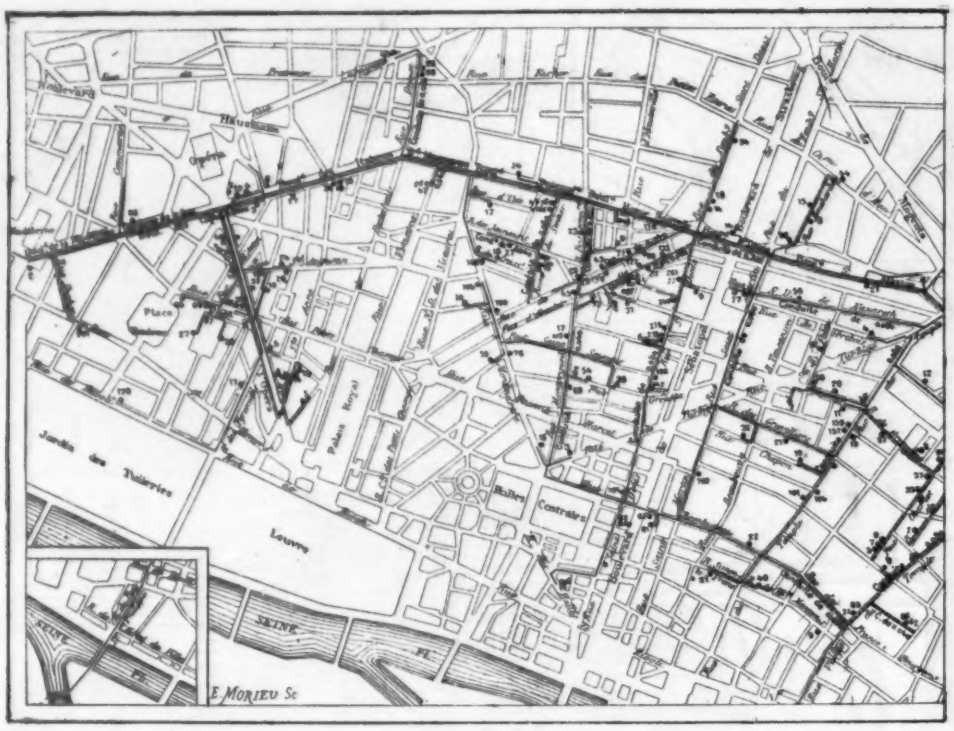


FIG. 4.—PLAN SHOWING AIR PIPE LINE.

As for the other group of boilers on the other side of the room, that comprises two Farcot boilers of the movable tube system, having a heating surface of 860 square feet each. The smoke is led beneath the floor to a chimney 80 feet in height. All the boilers save those of the Farcot group send their steam to a general collector, from which branch the pipes of the different engines. This collector can be separated into two parts by a sliding valve, so as not to interrupt the service in the case of repairs to a part of the collector. Moreover, the Mennier boilers have an independent steam pipe.

On coming from the compressors, the accumulated air is led into seven huge cylindrical reservoirs (R, Fig. 1), each nearly ten feet in diameter and forty feet in length, and having a capacity of 1,050 cubic feet. These receptacles, placed end to end, serve to collect and cool the compressed air. Two conduits parallel with the reservoirs permit of isolating any one of them for repairs, by means of sliding valves. It is even possible, if need be, to connect the engines directly with the city pipe line. The temperature of the compressed air should never exceed that of the outside air by 25° C.

The hot water of condensation of all the engines is collected in a general aqueduct, from which four Worthington pumps take it in order to feed the generators.

Another pump sends to a refrigeratory, *p* (Fig. 1), formed of several beds of fagots, the water of condensation, which, when cooled, is directed into the engine room through a channel from which the air pumps of the condensers suck it up.

A double system of piping permits of distributing the hot and cold water uninterruptedly in all parts of the works. The boilers are fed by feed pumps connected with the rods of the air pumps of the condensers, and by three Koerting injectors.

The city water, which is designed to replace the losses due to evaporation and other causes, passes into a purifier, where it is treated with a mixture of soda and lime. Here it gives up its salts until it marks less than 5 hydrometric degrees.

The works are lighted by a Gramme dynamo of 150 amperes and 40 volts, actuated by an upright 25 horse power engine, having two conjugate cylinders. A second and horizontal motor of 40 horse power with two coupled cylinders actuates a compound dynamo of the Thury system, of 150 amperes and 110 volts.

The lighting of the works and annexes, the house of the superintendent, the offices, etc., requires about 400 incandescent lamps and 25 Mornat arc regulators.

The principal system of piping is figured in the plans in Figs. 4 and 5. It consists of two large cast iron mains of 12 inches internal diameter. The first follows Saint-Fargeau, Menilmontant, and Pyrenees Streets, the Faubourg du Temple, traverses Place de la Republique, passes along the great boulevards on the side of the uneven numbers as far as to the Madeleine, where, through Royale Street, it joins the second great line.

This latter descends, parallel with the first, from the works to Pyrenees Street, continues to descend Menilmontant Street, and runs through Chemin-Vert Street, the Boulevard Richard Lenoir, Bastille Place, and Saint Antoine and Rivoli Streets as far as to Concorde Place, where it forms a junction with the conduit of Royale Street already mentioned.

The two main lines whose route we have just traced are intersected here and there by three large conduits, 12 inches in diameter, which divide the system into so many distinct sections. In the interior of these sections, which may, in part, be substituted one for another, or, rather, mutually supply one another, are distributed the distributing conduits properly so called, the diameter of which varies from 1¼ inches to 4 inches, according to the industrial importance of the locality to be supplied.

Here and there, the conduits are supplied with sliding valves and stop cocks for use in case of repairs, and which permit of isolating any small section of the line to be repaired, by the simple maneuver of two valves. Here and there, too, automatic siphons free the pipes of the water carried along by the air on its exit from the compressors.

The consumers' service pipes are provided with a cock with a collar which is put in place on the conduit at the point where the connection is to be made. The conduit under pressure is tapped by means of a drill maneuvered in the interior of the cock, which latter is quickly closed after the boring has been effected, the drill being pulled from the shell sufficiently to permit of this maneuver without allowing the air to escape. The branch is continued by an ascending column.

Before being employed by the consumer, the air

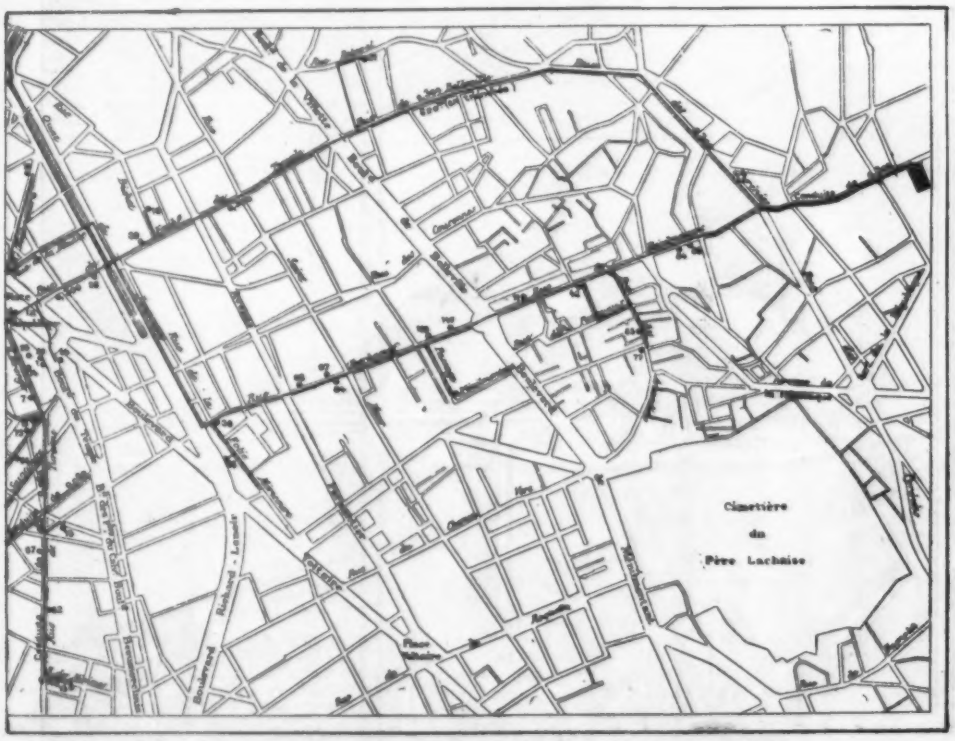


FIG. 5.—PLAN SHOWING AIR PIPE LINE.

traverses a pressure regulator, the object of which is to maintain a constant charge despite the variations of pressure in the mains. After its exit from the regulator, the air passes through a meter analogous to the gas meter, and thence flows to the utilizing apparatus.

Upon the route of the system of pipes a large number of stations are utilizing this power in the production of electric light. There are now in service about

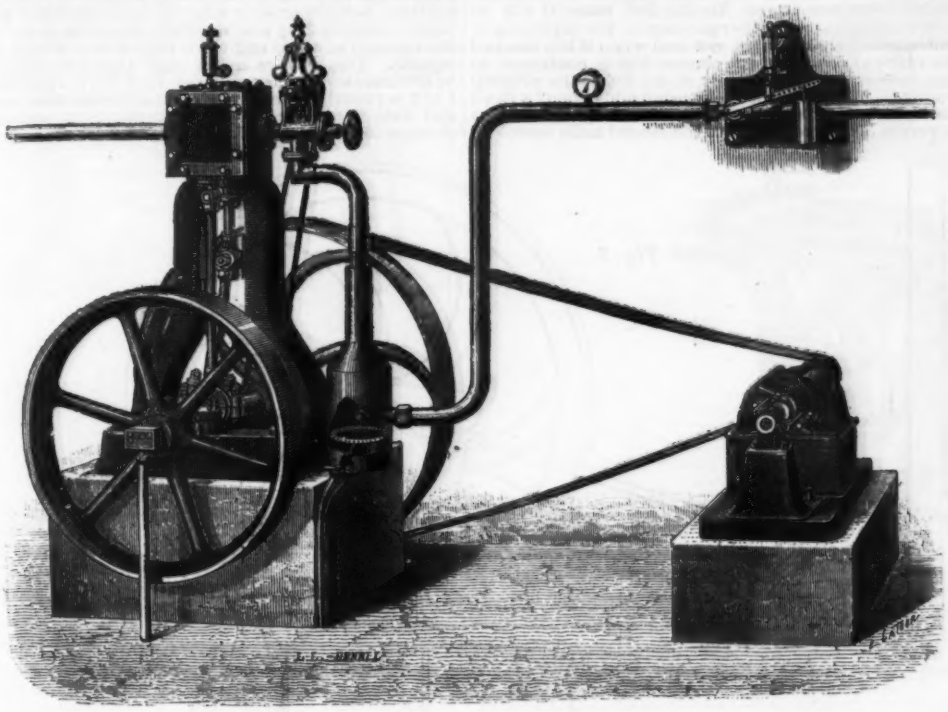


FIG. 6.—COMPRESSED AIR MOTOR.

4,500 incandescent lamps and 50 arc lamps of different systems serving for the lighting of restaurants, theaters, clubs, etc.

A new and particularly interesting installation that is to be made is that of the Varieties Theater, where compressed air motors are going to be substituted for steam ones.

Fig. 6 represents a type of compressed air motor actuating a Gramme dynamo. The compressed air, before its admission to the motor, is heated to a temperature such that upon its escape it shall not be less than zero, so as to prevent the formation of frost and the effects of congelation. It is necessary to heat it on an average to about from 6·5° to 8°.—*La Lumiere Electrique.*

THE FIRST CHINESE RAILWAY—CHINA, TIENTSIN, AND KAIPING RAILWAY.

The *North China Herald* gives the following description of the above named railway, the first and only one that has been built by the Chinese government, which was officially opened in October, 1888, by his excellency Hung-Chang. For some time previously, regular trains had been running upon both the Tientsin and Tong-shan branches.

The whole mileage is 86½ miles, with 10 miles of siding, or 28 miles from Tientsin to Tong-ku, which lies on the bank of the Peiho opposite Taku, and 58½ miles from Tong-ku to Tong-shan, near the city of Kaiping, where the Chinese Mining and Engineering Company have their works, kilns, and pits. It is difficult as yet to judge accurately the work of construction; after a year's steady working the line will speak for itself, but, so far as the work can be judged at present, it is of a thoroughly reliable and satisfactory character.

The Tong-shan branch has been completed for some time, and a large amount of very heavy traffic has been carried on it already; this road is, therefore, very compact, and runs as steadily and easily in most parts as some of the best lines at home.

The Tientsin branch feels new as yet, and the ballast of roadstone has not yet firmly settled; the work on this branch was rather hurriedly completed, so as to be in readiness for the Viceroy's projected visit; consequently, it does not run by any means as smoothly as the Tong-shan branch.

The permanent way is well ballasted with broken roadstone, such as is used for macadamized roads; the rails are bull headed, flange fastened with claw spikes to sleepers; these last are not creosoted, as is the case at home; it is found that the wood stands as well in its natural state as creosoted timber would, the life of a sleeper here being quite equal to that of those used on home lines. The joints of the rails are made with the ordinary English flange fish plates, bolts, and washers; there is very little tendency to slacken, as the nuts and washers readily "rust" to their places and hold very firmly.

The points are worked with the simple old fashioned hand switch, a complicated system of interlocking being quite unnecessary, and, indeed, quite unsuited for use by Chinese employes; the signaling is equally primitive, a red and a white hand flag completing the equipment of the signalman, who stands outside his hut and waves his signal in just the same style as those old peasants whom we see at the little level crossing cottages of the railways in the south of France. At important stations or sharp bends the signal flag is hoisted upon a high flag staff.

The greater part of the line is single, with loops at the stations; each piece of single line being worked with a train staff.

The bridge work is especially worthy of comment and praise; at Ku Tong, near Chun-liang-chang, is a very fine iron girder bridge, splendidly fitted together and so constructed that it can, at any time, be widened so as to admit of a double line of rails; another equally good piece of work is the girder and swing bridge across the Pehtang River, a stream considerably wider than that at Chun-liang-chang; these two bridges were erected respectively by Mr. Vowel and Mr. Ricketts, acting under the engineer in chief, Mr. Kinder, and are at once an ornament to the line and a credit to the engineers.

The trains are rather strangely made up, carrying both passengers and goods at the same time; immediately behind the engine is a long second class car partitioned down the middle, and having sitting accommodation along the sides of the car, and on either side of the partition; in these cars the ordinary Chinese tradesman travels; next comes a long open truck, doing duty as a kind of third class, having plank seats all round and piled up in the middle with baggage, fruit, fish, and merchandise of all sorts; the Chinese laborers travel in this "carriage," which is also supplied with plenty of tarpaulin to protect both passengers and freight in case of rain; next comes the first class car, built after the model of the American cars; those on the Tientsin branch are very fine and comfortable, but those on the Tong-shan line are only temporarily in use, and might well be improved and provided, like the Tientsin cars, with lavatory and private coupes; behind the first class cars come baggage wagons and trucks *ad lib.* All the carriages and trucks are connected by American spring buffers and claw couplers, and the whole makes a long and more or less imposing train. The engines are driven by Europeans, and each train is under the charge of a European conductor, assisted by two or three native collectors and brakemen.

Starting from Tientsin at 9 A.M., forty minutes' run brings you to Chun-liang-chang, and forty more to Tong-ku, the train stopping only once on the journey. The half hour's waiting at Tong-ku is by no means pleasant, for though a fine hall of reception has been erected there for the Viceroy to occupy on the opening day, the station is without any proper waiting room accommodation for first class passengers, who have to stand in the midst of a crowd of excited and anxious Chinese in the booking hall, and to submit, as the writer did, to be questioned as to which is the proper train, and whether it will go before the time, and if one could get on if he went to meet it, and as to what railways are like in Europe, etc., all of which may afford a good half hour's amusement for the first time, but is likely to grow wearying with repetition.

At 11 A.M. the train for Tong-shan starts; half an hour's run brings you to the Peh Tang River, and the fine bridge already referred to in a little over an hour more; passing Hanku at 0 15, you reach Lutai, the most important station on that part of the route; here the railway company have extensive buildings and some resident foreign officials.

Another hour's run reaches Tong Fong, a small roadside station, and half an hour more brings you to Su Ko Chwang, where the company have engine sheds, repairing shops, and quite a busy establishment.

In about half an hour more you come in sight of the two great hills from which Tong-shan takes its name, and by 3 o'clock you arrive at the terminus, which is by far the neatest and best appointed station upon the whole line.

The whole journey of about 100 miles is completed in 5¼ hours, not reckoning the half hour's waiting at Tong-ku; the average speed is nearly 20 miles an hour, and would be greater, but for the many rather critical pieces of road, where it is necessary to slacken considerably; when the ballast has been thoroughly well packed in, and the line has settled a little more, the company intend to run trains regularly at between 30 and 40 miles an hour.

The fares are very reasonable, $1 30 covering the expense of first class accommodation for the whole journey; the line is evidently very popular, and large numbers of Chinese travel by it daily; they do not seem to fear the speed, and innocently remark: "This compared with riding in a cart is quick." Immense quantities of goods going inland and of coals, earthenware, and bricks coming to the coast are also carried daily, and the line is bound to be a thoroughly good paying concern.

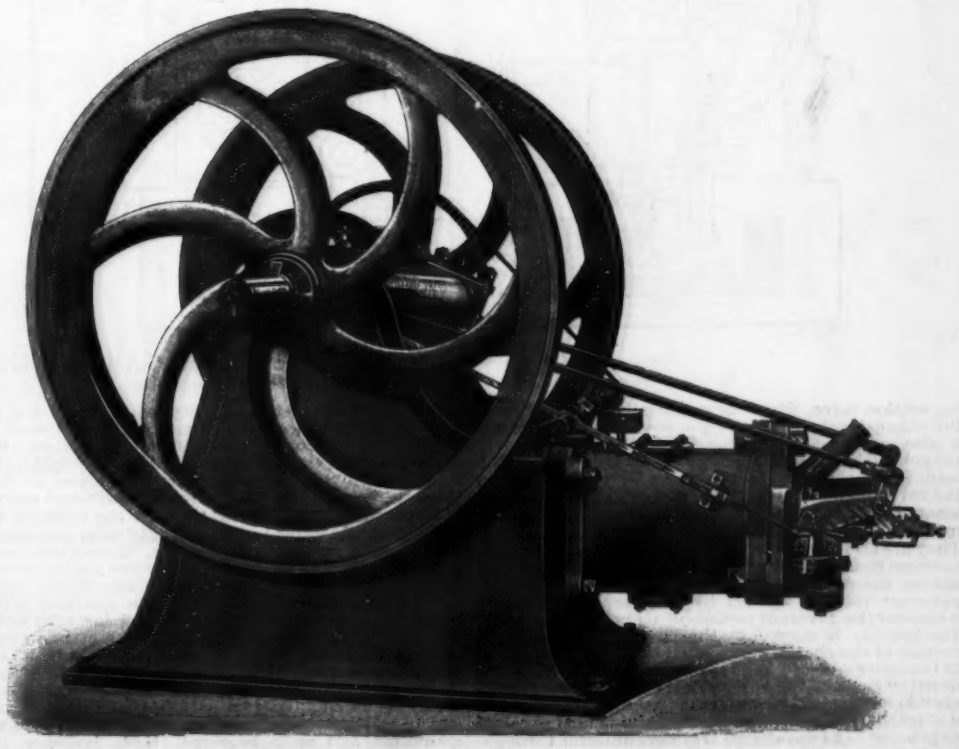
It does great honor to those who have worked long and hard against prejudice, opposition, and physical difficulties to complete it, and one would think there should be little doubt but that its obvious usefulness will induce the powers that be to promote another line, and by the starting of a railway through Southern Chihli, Shantung, and Kiangse, open up the great orchard country of Shantung and develop more fully the industries of the interior.

IMPROVED GAS ENGINE AND PUMP.

WE illustrate a six horse power Atkinson gas engine, partly by a perspective view and partly by detailed engravings (Figs. 1 to 3). We also illustrate the same engine combined with a pump, Figs. 7 to 12 Figs. 4 to 6 are indicator diagrams. We are indebted to *Engineering* for our engravings and the following description.

The six horse-power Atkinson's "Cycle" gas engine has a cylinder 9½ in. in diameter. By means of the linkwork the piston has imparted to it four strokes for each revolution of the crankshaft. These strokes all vary in length, being as follows: Suction stroke, 6⅞ in.; compression stroke, 5 in.; working stroke, 11⅛ in.; and exhaust stroke, 12⅜ in.

The cycle commences, say, at the end of the exhaust stroke, the piston at this time being as close to the end of the cylinder as is compatible with safety, thus driving out practically all the residuum, which is still further cleared out by the momentum of the exhaust gases in the exhaust pipe dragging a little air through the passages and small clearance space left. From an economical point of view it is now pretty well under-



SIX HORSE POWER GAS ENGINE.

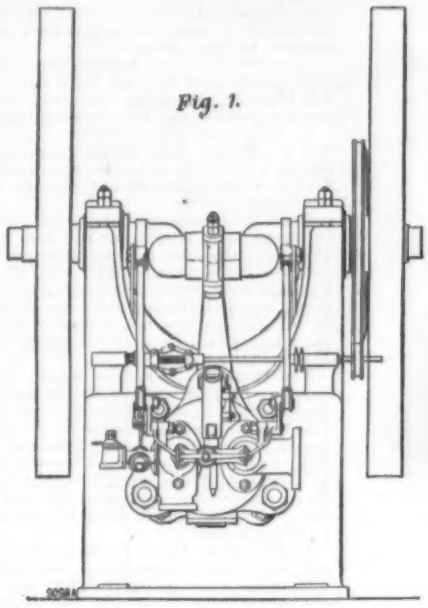
stood that the total elimination of the burned gases is a desirable feature; in fact, engines have recently been made which sacrifice an entire revolution for the purpose of obtaining this desirable object.

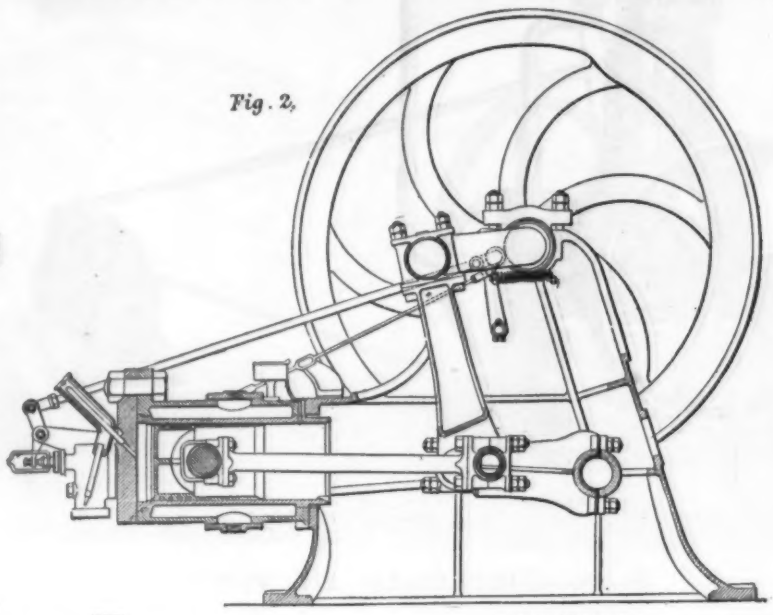
A short suction stroke is now made, followed by a slightly shorter compression stroke, the difference in the lengths of these strokes leaving a chamber into which, together with the clearance spaces, the charge is compressed. At this time ignition takes place and a long working stroke is made, followed by a slightly longer exhausting stroke when we arrive at the completion of the cycle, the whole being performed during one revolution of the crankshaft.

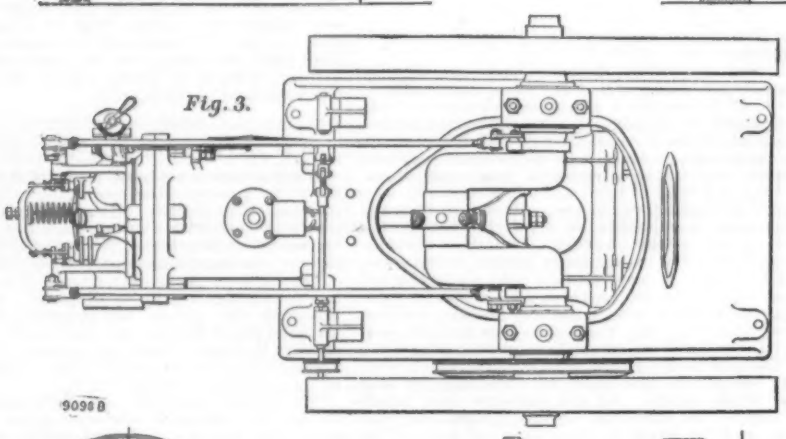
It will be seen from the views given herewith that this arrangement of engine lends itself to great simplicity of construction, as well as economy. There are only three valves in the engine, the exhaust valve, which is similar to that commonly used in most gas engines, this position gets rid of what has hitherto been the greatest source of trouble with gas engines. We are informed that several of these engines have worked for six months, ten hours every working day, without a valve being removed for cleaning, without the piston being taken out, and without a single bearing being adjusted. This seems coming within measurable distance of the simplicity and certainty of a steam engine.

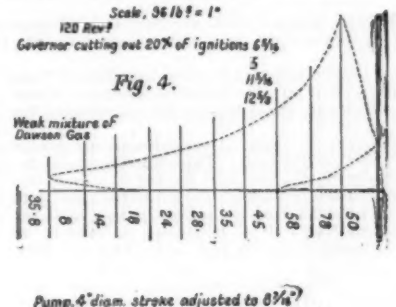
The great economy of these engines is obtained mainly from two causes. In the first place, it will be seen that, unlike any other gas engine, the expansion of the ignited charge does not end when it has reached the original volume of the charge, but is continued to any desired extent, generally about twice the original volume. This continued expansion adds about a third more work for the same consumption of gas; its value is very much increased from the second main source of the whole width of the engine, is lined with white metal, and thus takes this heavy shock without any straining and with very little friction or wear.

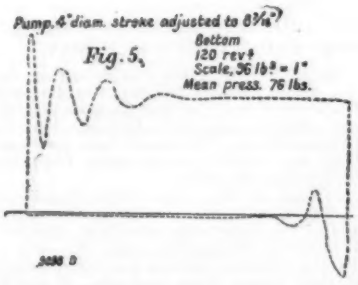
Taking an ordinary diagram from one of these engines, the pressure on the crank pin and main bearings never exceeds about 35 per cent. of the maximum pressure on the piston. The work done in the cylinder during the early part of the expansion is also transmitted more gradually to the crank pin, so there is not the jerkiness in running so commonly associated with gas engines; combining this with the ignition, every revolution controlled by a wonderfully sensitive governor, the running of these engines is remarkably steady and regular. The makers assert that when everything is in first-rate order, they will not vary more than from 1 to 2 per cent. between maximum and minimum loads, and that it is perfectly immaterial how suddenly changes in the working load are made.

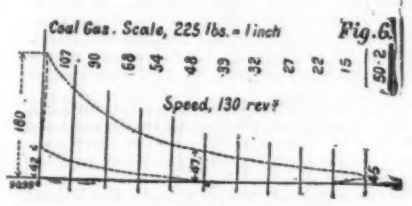


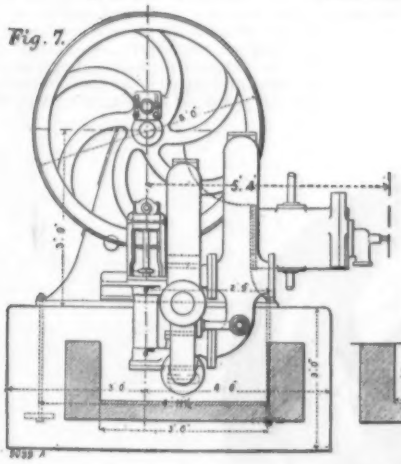


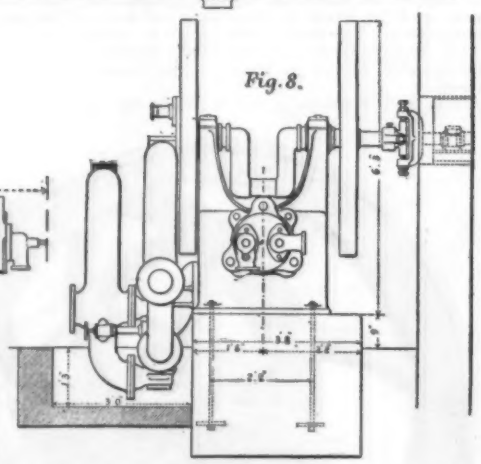












SIX HORSE POWER GAS ENGINE.

the suction valve, which is practically a duplicate of the exhaust valve, and the gas governor valve, which is also similar to those commonly used for the same purpose. The exhaust valve is opened by a cam on the main shaft, the cam rod working a lever which opens the valve. The suction valve is operated in a similar manner. Both these valves open inward, so that any pressure in the cylinder tends to keep them closed. They are also closed by one spring, which is arranged between them, operating through a yoke which presses against the ends of bridles on each of them. The gas governor valve is opened by the suction valve cam whenever the governor permits of its being so opened. The ignition is caused by the compression forcing a portion of the charge into a small tube, which is closed at the outer end and kept red hot by means of an external "Bunsen" burner. There is no valve in connection with this ignition arrangement, the timing of the ignition being caused by the chimney being raised or lowered. As the charge is always uniform throughout its volume, this gives a sufficiently regular ignition for practical purposes, and doing without a valve in economy, which is the rapidity with which the expansion takes place. Other gas engines expand to original volume during one-half of a revolution; this one expands to original volume during one-eighth of a revolution, so that work is done four times as fast. When it is understood that one of the greatest sources of loss is the passage of heat through the walls of the cylinder to the water jacket, it will be seen how necessary it is to do the work rapidly. From this cause the expansion line of the diagram when the expansion has taken place as far as original volume will be found to be from 5 lb. to 10 lb. higher (it is generally about 45 lb.); this leaves a considerable pressure with which to continue the expansion. The terminal pressure is generally about 14 lb., which gives a quiet exhaust and a better opportunity for the gas to be thoroughly consumed during the working stroke.

In all gas engines there is a heavy initial pressure, which in every other instance is transmitted to the crank pin and main bearings. Here, however, this heavy pressure is transmitted directly to the long bearing of the vibrating link. This bearing is made

The combined engine and pump illustrated has been supplied by the British Gas Engine and Engineering Company, Limited, London, N. W., to the Wimborne Minster Water Works Company, Dorset. The installation consists of a 6 horse-power nominal Atkinson's patent "Cycle" gas engine working a double-acting pump direct, the engine being driven by "Dowson" gas, the apparatus for which was supplied by the Dowson Economic Gas and Power Company, Limited, of Westminster. Compared with the kind of plant very frequently supplied for similar purposes, this forms a remarkably compact and economical arrangement. The engine and pump occupy a floor space of only 7 ft. 6 in. by 7 ft., and the gas plant 9 ft. 6 in. square.

The pump (Figs. 10 and 11) is 4 in. in diameter, and the stroke can be adjusted from 8 in. to 12 in. It pumps from a suction reservoir placed underneath the engine room floor, and delivers through a 6 in. rising main into a storage reservoir situated on a hill commanding the town of Wimborne, the rising main being 816 yards long, the total lift of the water 171 ft. The plant has

only lately been erected, and a preliminary run was made on Saturday, October 20, 1888, particulars of which are as follows:

The trial was made for five hours, the engine running throughout at 120 revolutions per minute. The indicator diagram (Fig. 5) was taken from the pump, from which it will be seen that its full capacity was being delivered. An engine indicator diagram (Fig. 4) was also taken at the same time, the gas consumption being also taken by observing how long it took for a gas holder 6 ft. in diameter to fall 4 ft. The engine diagram is by no means as full as can be taken with "Dowson" gas, but as the engine was only taking 96 ignitions per minute the gas was reduced so as to give

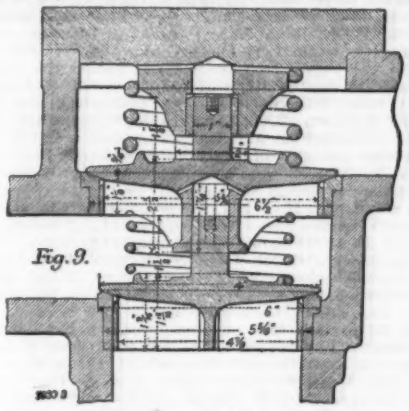


Fig. 9.

this diagram. Below we give the result of this preliminary test;

Indicated horse power in engine.....	6·951
" " pump.....	4·538
Actual horse power in water lifted...	4·5
Dowson gas per hour...	542 cub. ft.
Equivalent in coal consumption.....	7·74 lb.
Dowson gas per indicated horse power in engine.....	78 cub. ft.
Equivalent in coal consumption.....	1·11 lb.
Dowson gas per actual horse power in water lifted.	120 cub. ft.
Equivalent in coal consumption	1·706 lb.
Combined efficiency of engine and pump.....	63·46

When it is understood that this plant was only started for a couple of hours the previous day, the above figures are astonishing; and as the makers state that rapid improvement will take place in the working of the engine and pump, they assert that it is the most economical pumping plant ever erected, and though slightly better figures have been obtained from first-class compound engines of large size, we feel inclined to agree with them, as the saving in first cost of machinery and buildings must also be very great.

that the pump must have worked in a very satisfactory manner. We doubt also whether it would be possible to attain such a high efficiency by using any system of geared pumps. It will be needless to state that a plant of this description can be erected for very much less outlay than if geared pumps had been used; not only would the engine and pumps have cost more, but also the foundations and buildings; the cost for maintenance would also be very much increased.

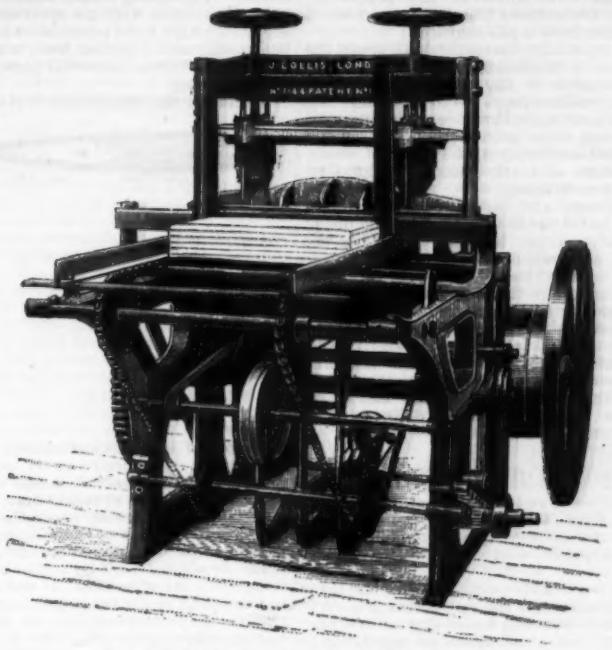
To enable the engine to be started without the load of the pump, there is a by-pass from the delivery to the suction. A reflux valve in the delivery valve just beyond keeps the delivery main charged.

We cannot but think that there must be numerous instances in which a plant which is so economical in first cost and working could be adopted with advantage, where the cost of enormous engines, geared pumps, and high buildings has been prohibitory.

MACHINE FOR BRANDING WOOD.

IN certain industrial establishments the branding of a name and trade mark upon models, packing boxes, this kind are now regularly employed in several great transportation enterprises and in breweries, distilleries, and manufactories of preserves.

At the last exhibition of brewery apparatus at London, especially, two of these machines were shown, one for marking with a cold and the other with a hot iron,



MACHINE FOR BRANDING WOOD.

both devised by Mr. J. Collis. The last named machine we shall now describe to our readers.

To allow the main idea that led to the conception of this apparatus to be understood, we give a description of the form in which it was first constructed, and a perspective view of the present machine, provided with useful improvements. The work table, supported by two cheeks, receives the furnace, which consists of a box, surmounted by the branding iron to be heated. In the interior, the furnace is divided by partitions into several compartments containing perforated tubes in which gas led by tubes is burned. Air is introduced at the same time to support the combustion. Between the table and the cheeks there are slides in which move the uprights of a frame closed at the top and bottom by crosspieces. A transverse piece is connected with the upper crosspiece by screws, and, through four freely

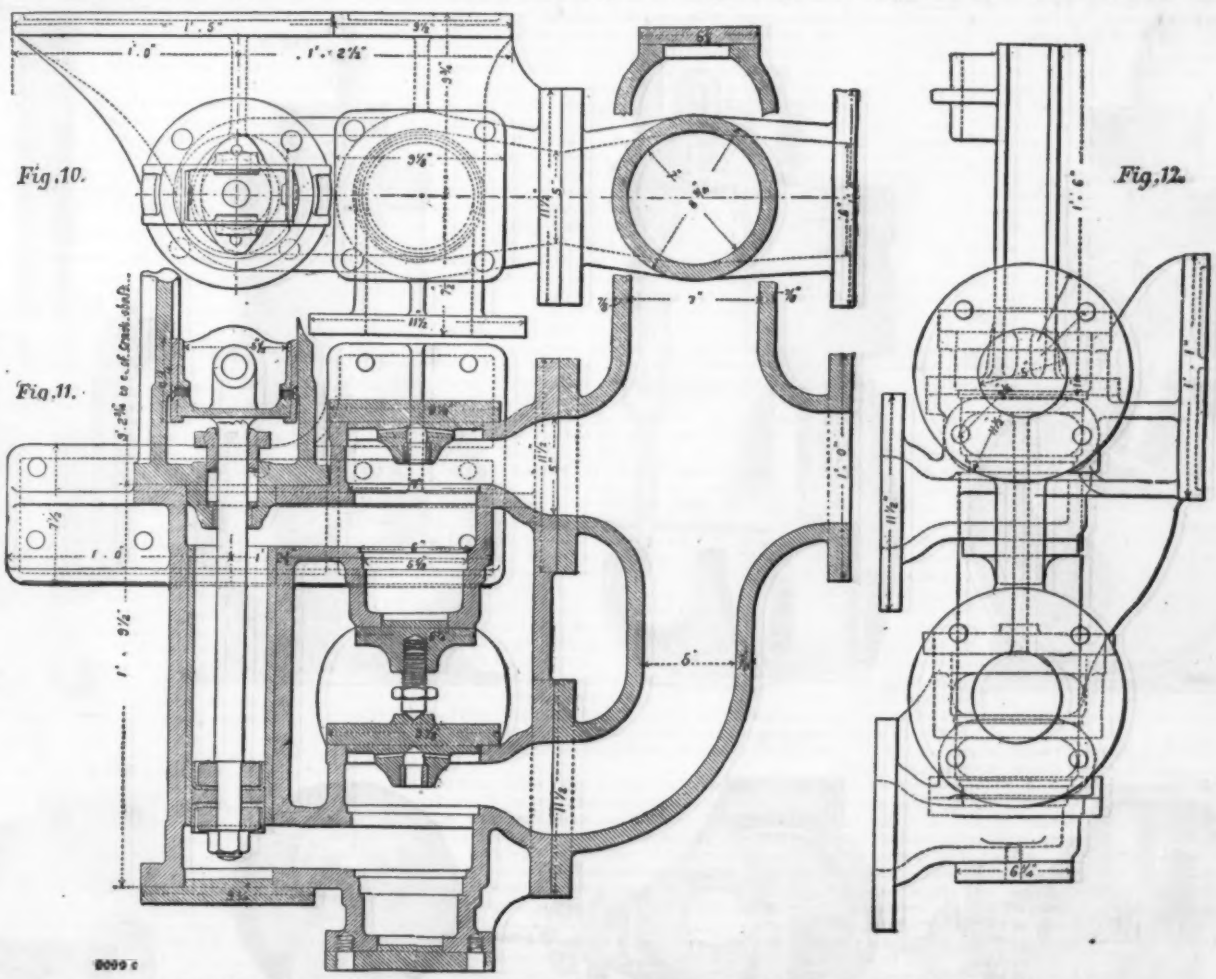


Fig. 10.

Fig. 11.

Fig. 12.

DETAILS OF SIX HORSE POWER GAS ENGINE AND PUMP.

Although the pump was running at 120 revolutions per minute, the valves (Fig. 9) worked without the slightest shock. They are of very large diameter, are guided top and bottom, and have strong springs fitted to them. The loss by friction in valves and rising main was only 0 038 of a horse power, so it is evident casks, and pieces of wood entering into the construction of machines is a tiresome operation that constitutes one of the most disagreeable duties of the shop. Several attempts have been made to substitute for the branding iron a machine for obtaining the same result, but with the production of more work. Some machines of moving bolts, carries the head of the press. Between these two latter parts there are spiral springs, which transmit a strong pressure, and at the same time prevent breakages. According to the height of the pieces to be branded, the crosspiece is raised more or less by revolving the hand wheels of the screws. The frame,

during the work, has an up and down motion, which is given to it by winches fixed upon the crosspiece, and connected with eccentrics keyed upon the shaft. Upon this latter there are tight and loose pulleys for the reception of a belt.

The general arrangements of the improved machine are sensibly identical with those of the preceding. They may be readily understood from an inspection of the cut, which is taken from a photograph.

This machine is especially distinguished from the other by the addition of mechanism designed to effect an automatic performance of the work. Thus it requires but a child to produce from 700 to 1,200 imprints per hour. When a pile of boards has been laid upon the table, no attention has to be paid to them, for, owing to the automatic feed mechanism, they pass of themselves into the machine and are branded without requiring any special surveillance.

This machine is strong and is well constructed. A great saving in manual labor is obtained by the use of coal gas in a closed furnace, and the latter has the advantage over the old system that it gives rise to no danger from fire. The machine is provided, too, with an exhauster that sucks up the smoke produced by the branding iron and by the gases given off by the furnace. These products are carried outside of the shop, and thus do not vitiate the atmosphere.

Finally, the imprints obtained with this machine are deeper than when the operation is done by hand; and, consequently, they withstand friction and scraping better, and this is far from being displeasing to manufacturers.—*Revue Industrielle.*

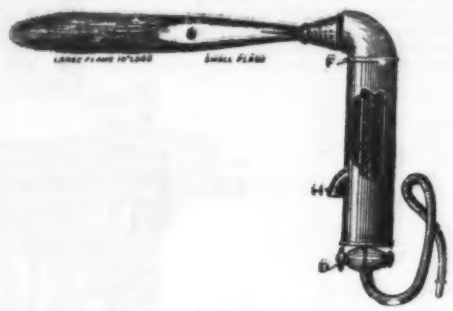
AN IMPROVED BLOW PIPE.

THE illustration gives a general view of a new portable blow pipe, Rawlings Brothers, London, which for its simplicity and novelty is worthy of notice, especially as this is an appliance often wanted by engineers and others.

Perhaps the most remarkable point about the present blow pipe is that, although the apparatus is only 10 in. long, it is possible to obtain a flame of good combustion 12 in. long, which can at all times be regulated to give any smaller size, down to that which would be obtained from a candle, by simply rotating the plug of the cock, which regulates the size of flame without making scarcely any difference to the blowing. Apart from the large flame, there is always a pilot light burning inside the nozzle, which continues to burn when blowing has ceased. The nozzle is arranged to promote combustion and protect the flame from the wind, and by this arrangement the appliance can be worked in a strong wind with the ease of a gas blow pipe. A point in its favor is that, by means of an absorbent, the apparatus is made perfectly safe against fire, and because of its construction it is impossible for any loose fuel to drop out. This is proved by the fact that the blow pipe can be worked in any position, or whirled round by the flexible tube, and the flame will continue burning even in an excessive wind.

The fuel used is benzoline, and the blow pipe is constructed entirely of brass and copper. The body consists of a piece of brass tube 1¾ in. diam., at one end of which is the cock, D, and at the flame end is the perforated nozzle, F, which contains a deflecting cone, wick tube, and vapor jet nozzles. Within the casing there is a curved wick tube, an air tube, and a jet tube (as seen in section), which passes through to the point of ignition, and which terminates at the center of the nozzle. The filling nozzle is shown at H, and the wick tube terminates with an open end about 1 in. from the cock. The air tube terminates at the nozzle end inside the casing, and a cotton wick is placed inside the wick tube, with fibrous material packed around the tube to fill the casing.

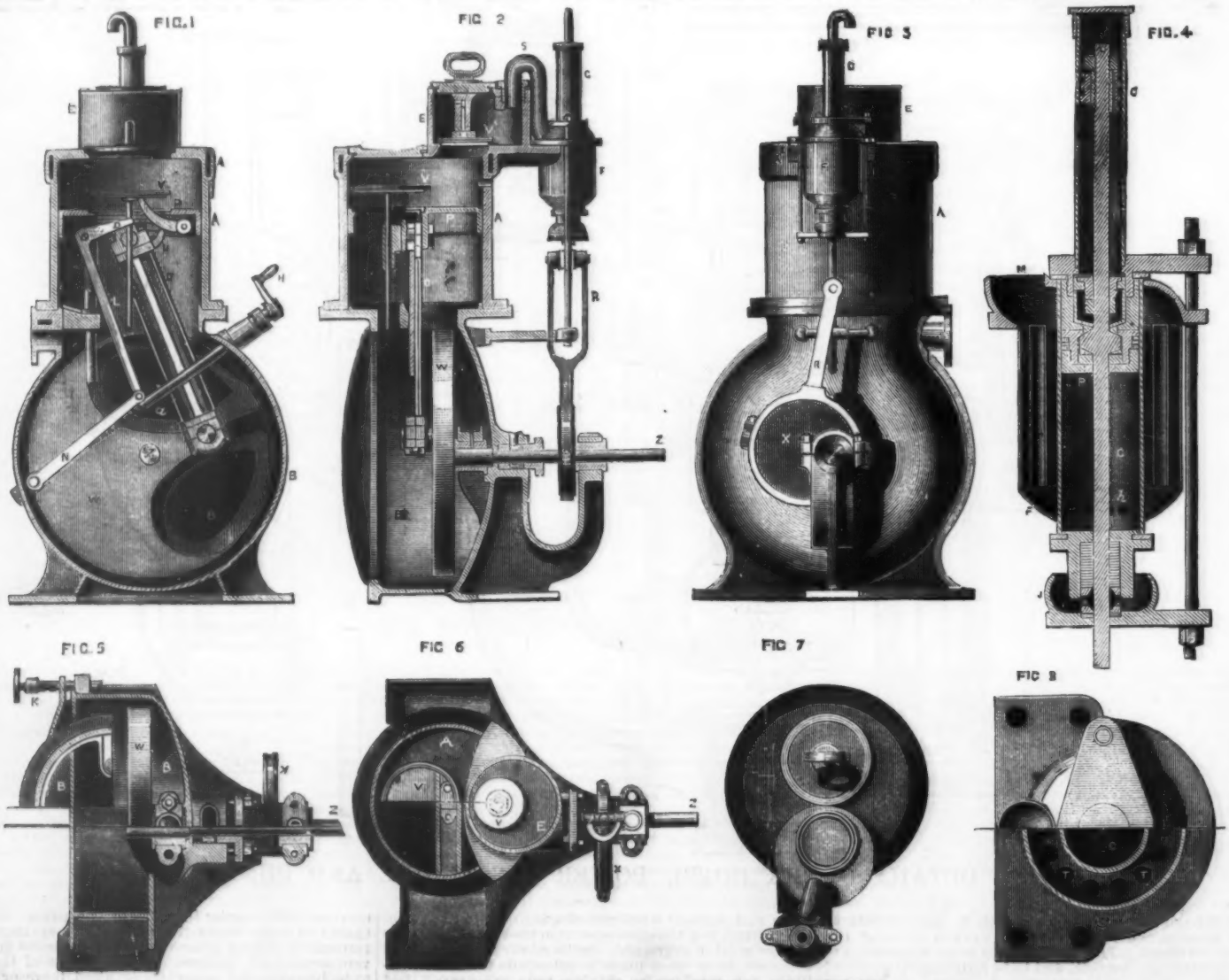
To charge the apparatus, it is held vertically and the



fuel poured in until sufficiently charged. The unabsorbed fuel is poured out by same nozzle in the same way as the old benzoline lamps were charged. By this arrangement it is evident that the liquid fuel cannot enter the wick tube or reach the jet nozzle. The cock is constructed with three passages, one admitting air to the other two, which when the plug is rotated can be made to send a blast by either the jet or the air tubes, or both at the same time. It will be seen that if by turning the plug the blast is first turned on to the jet tube, there is only the pilot light to give the required flame; but on rotating the plug, the air is sent partly by way of the air tube, which circulates through the fibrous material, and consequently is charged with vapor, which comes down and enters the wick tube and passes up to the jet nozzles, and so increases the size of flame. If all the air is sent by way of the air tube, it issues at sufficient velocity to cause, by induction, a sufficient supply of inflammable vapor, which is primarily ignited by the pilot light inside the nozzle.—*Industries.*

IMPROVED ICE-MAKING MACHINE.

THE ice-making machine illustrated by the engravings is of a novel and ingenious character. It is of the vacuum type, but new and simple in design. The vessel for the water to be frozen is not shown, but it may be of any desired form, and is connected to the case, B, or lower part of the cylinder, A, by ordinary pipe connections. In the engravings, Figs. 1, 2, 3, 5, 6, and 7, A is the cylinder of the large or vapor pump; B, the chest containing the crank and counterpoised flywheel which works the vapor pump pistons in cylinder, A; Z, the shaft passing through the stuffing box into the chamber, B; E, the exit valve chest; S, passage from exit valve chest to condenser, F, through G, the ejector pump; X, an eccentric which works the ejector pump, G; H, a screw and handle to work the large valve when starting a vacuum. The single action vapor pump with piston in the cylinder, A—which is worked by the crank and flywheel contained in B, driven by a pulley on the shaft, Z, through a stuffing box—draws the vapor from the ice box through a valve, V, in the piston, and delivers the compressed vapor—which is prevented from condensation by the warmth of the cylinder heated by the steam jacket, A¹—through the exit valve chest, E, into the condenser, F, where it is condensed to water and ejected, together with any air that may have leaked into the machine, by the pump, G, worked by the eccentric, X. The drawing off of the vapor from the ice box causes the water to evaporate rapidly until it has given off all its latent heat, when it turns to ice, but before the heat of the water is drawn off, all the air must be exhausted out of both the machine and the water, and to do this with the large pump would require enormously more power than to drive off and compress the vapor which arises from the water in the ice box; but by screwing down the hand nut, H, Fig. 1, the position of the vibrating arms, N, is altered, so that the lever, L, by means of the finger, D, at its upper end, prevents the valve, V, from taking its seat for any desired portion of the first part of the delivery stroke of the piston, P, in the cylinder, A, allowing the air thereby to return to the cylinder and the chest, B, thus reducing and regulating, as may be desired, the power required in getting up the vacuum. The air pump, C, and condenser, F, seen in Figs. 1, 2, and 3 in one form, are shown to a larger scale in Figs. 4 and 8. The vapor pipe, S, Fig. 2, enters the condenser at M, Fig. 4, and the vapor thus enters the tubes, T, which are surrounded by water. The vapor enters the pump by holes, H, and is pumped away by the two pistons of the air pump. The pump we do not describe at length, as this particular form has been replaced by a simpler one. The action of the machine is very simple. The little air pump, G, pumps away the air out of the whole interior of the machine. This vacuum fills itself with water vapor from any vessel containing water put in connection with the machine. The large pump, A, then compresses the vapor contained in it; this compression of the vapor increases its temperature, and would cause it to condense into water in the cylinder if it was allowed to lose its heat to the cylinder, and in this case the condensed vapor to be ejected would be so small in quantity that it would not be forced through the exit valve. To prevent this loss of heat of the compressed vapor and its consequent condensation into water in the cylinder, Messrs. Southby & Blyth heat the cylinder to a temperature above that at which the vapor will condense, and in this way the compressed vapor can be almost entirely forced through the exit valve into the condenser, F, inclosing the cylinder of the little air pump. There it is condensed into water, and from it is drawn and ejected into the air by the air pump, together with any air that may have found ingress into the machine. It will be



IMPROVED VACUUM ICE-MAKING MACHINE.

seen from this description that the two points of this invention which cause its success, and without which little or no ice would be made, are: (1) The use of two pumps, one a small one to relieve the whole of the machine of the pressure of the atmosphere, the other a very much larger one to compress the vapor arising from water contained in a vessel in connection with the machine, and so to force it into a condenser; (2) the heating of this larger cylinder, so that the compressed vapor may not condense in the cylinder.

As to the power required for driving with so rarefied a fluid as the vapor of water at low temperatures, the pressure on the piston is of course very small. The initial pressure of the vapor as it rises from the water at a freezing temperature being 0·185 in., or say 0·15 in. in the cylinder, and the final pressure that will cause it to condense on a condenser cooled by water passing away at 100 deg. would be 2 in., which would give an average pressure of about one-sixth of a pound on the piston. With so small a maximum pressure very light piston rings are all that are necessary, so that with a well lubricated piston the friction is very small indeed, and tests of the power used show this, we are informed, to be very small, and remarkably so for small machines; and there is, of course, no other expense, as it is free from all expense for chemicals.

Some minor details conduce to the success of the machine, more especially as regards starting it. When starting the machine, air at a comparatively high pressure has to be dealt with, occasioning an adverse pressure on the piston of, say, 7½ lb., or some forty-five times that of the working pressure. Then the air, being non-condensible, will not disappear on compression in the condenser, as is almost always the case with water vapor. The difficulty has, however, been overcome by using a by-pass valve, opening a communication between the two sides of the piston, and capable of being closed at any point of the stroke, so that when starting this valve is kept open all but, say, for $\frac{1}{10}$ at the end of the stroke, and is closed at earlier points of the stroke as a more perfect vacuum is obtained. It is kept closed altogether when all the air has been expelled. This by-pass is effected by the levers, NLD, as already described. All the joints of the valves, as well as of the covers, are of peculiar construction, and consist of a narrow shallow bead round the valve, or opening for the valve, closing on a more or less elastic bed, such as vulcanized India rubber or fiber, which has been found to answer well. The valves also have to be of very large capacity to enable the machine to work at high speeds, and have to be actuated. The mode of actuating it by the finger, U, on the upper part of the connecting rod will be seen in Fig. 1. The water being cooled may, as in the case of cold store chambers, be in pipes, etc., any distance from the machine, and salt water may be used in some cases with economy and advantage.

The makers specially intend the machines for ice making on board ship, or in confined places, or where the escape of injurious gases would be dangerous, and for making ice by hand power. The quantity of cooling water for the condenser is very small indeed, and by the addition of an extra cylinder and some increase to the power required for working, the cooling water can be dispensed with altogether. It is also noteworthy that the production of ice commences within a few minutes after starting the machine. A machine placed where most convenient, in a brewery, for instance, can cool vats of water for refrigerating or attemperating in various parts of the brewery. For working cold chambers, ice may be produced in sealed vessels placed along the top of the cold chamber by a machine worked at a distance, and only connected to the sealed vessels by a pipe, in which case the ice machine need be worked only when the ice in the vessel is nearly dissolved and requires to be refrozen.—*The Engineer.*

[Continued from SUPPLEMENT, No. 683, page 10913.]

ELECTRICITY, LIGHT, AND HEAT.*

By Prof. C. F. BRACKETT, of Princeton College.

Now, to make a long story short, it may be stated that Hertz has for some time been studying the oscillatory discharge, and his more recent labors have thrown a great deal of light upon them. I will not allude to all of his experiments in order, but only mention such of them as best suit my purpose. In order to understand one of them, consider a simple experiment in acoustics. A long rod of wood or metal is held firmly between the thumb and finger, at its middle point. If it be pulled gently with the other hand, which has been powdered with a little powdered resin, the rod breaks into a clear musical note, as clear as that of a violin. The effect of the friction has been to produce a series of condensations and rarefactions which travel along the rod, thus showing that it is in vibration. Hertz arranges a long wire with a metallic conductor of considerable capacity on each end. The wire is cut apart at the middle point, and the ends so made are brought in contact with the discharge rods of the induction coil, which are furnished with small bells, between which the spark can pass. A small rectangle of wire with one side cut open at the middle, and the two ends armed with small adjustable balls, serves to show what is going on in the long wire system just described. This it can do by the presence or absence of a spark at the opening between the balls. When the induction coil is set in operation, the electrical oscillations in the primary system are shown by the induced sparks in the rectangular system. If the periods of oscillation in the two systems be made as nearly as possible the same, the brilliancy of the spark in the secondary is much increased—just what should happen on the principle of resonance. There are then waves set up in the conductor, and their frequency can be calculated. Now, according to the electro-magnetic theory of light proposed by Clerk Maxwell, the disturbance which constitutes electrical induction should travel with the velocity of light, or about 185,000 miles per second. It is then easy to find the length of the oscillations of any given number of alternate discharges, such as are produced in the experiments of Hertz, for we have only to divide this distance, 185,000, by the number which gives the length of one, provided we may assume that the disturbance is propagated in the wire with the same velocity as a disturbance is propagated in the air. Hertz, however, found that this is not the case. His experiment was carried out somewhat in this way: Two large metallic plates were furnished with wires terminating in knobs and so placed as to be in the same vertical plane, with the knobs near each other, so that a spark could pass when the two were connected with the induction coil terminals. Behind one of the plates was placed a third so as to be parallel to and near it, and from this a wire was led to a considerable distance away and put to earth. Any electrical disturbance in the plates joined with the induction coil would, of course, induce a corresponding one in the third plate, and so on in the wire connected with it.

Suppose we want to find out whether there is anything going on analogous to the transmission of waves in sound, we would go alongside of the wire and see if there is a place where there is a ventral segment, and, further, if we find that repeated again and again, in other words, we ascertain if there is a series of waves—what kind of a glass shall we employ for this purpose? All we have to do is to make a little induction coil, put a knob on each end of the coil, and bring them near each other, and see whether a spark passes. Suppose the wire be stretched here (illustrating with an imaginary wire), we look carefully and find a spark passes. Then passing along the spark grows dim, now it grows a little stronger; we find it here very strong; we pass right on, and find that when we go over the same distance again, it increases and diminishes. When we do this, we find the distance between the nodal points. In other words, I find the results absolutely, the result we were looking for, by the inductive effects in the wire. (Applause.)

Now, I will not weary you with that part of the thing, for there are a great number of experiments which can be tried. We can find this instance. When the wire transmits these electrical disturbances, there is in the ether, or in the air, close by its side, another disturbance transmitted; that is to say, we have the one taking effect along the wire and the other taking effect along the ether. Now, do they travel with the same or with different velocities? You will find by making connections across the various points, and you will find certain points where there is no motion between those two; but if you string them in down here to a point where there is a movement, you will find in other words the rate of transmission in the wire is different from the rate of the transmission in the ether. Hertz finds that if he employs iron wire, copper wire, or zinc wire, or wire of any other metal, it makes not the slightest difference in the position of the nodal points. In other words, the length of the wave remains unchanged, and it makes not the slightest difference whether the diameter be small or great.

Now, let us look at what light is for a moment, and then we will see how we should produce it. I have already stated that light is a motion transverse to the line of progress of the wave. I am going now to ask you to follow me through a little severe thinking.

Faraday in the height of his enthusiasm as an experimenter endeavored to connect gravitation directly with electricity. He made coils of wire and threw them out of an upper story window and let them fall down to the earth field in order to see if he could get any galvanic disturbance. Faraday had already investigated an action closely analogous to that of gravitation, for he, more fully than any one else, explained or rather described the character of the region about a wire which is conveying a current of electricity. Here is a wire and a current. Suppose a current is passing directly down through it. I need not discuss now what a current is, but will take it for granted that the wire joins the brushes of a dynamo machine. Now, bore a hole in a glass plate, push the wire up through the plate, send the current down through the wire, sprinkling some ordinary magnetic sand, such as was once used on the writing desk, all about this. When the current passes, we shall find on gently tapping the plate that there are arranged certain well marked lines around the wire in more or less perfect circles. Now, we have mapped out what are called circular lines of force, and the region is called a field of force. Let us see what properties this has. If in such a region we bring a pole of a magnet, and this be perfectly free to traverse around it, we shall have this magnetic pole revolving along these lines of force, and when it has gone around the circle, a certain amount of work will have been done. Suppose in order to make clear we split the conductor down to the axis here (showing with a pencil), this way here, and so on, turning through a certain number of degrees each time, and in every one of those splits we insert a card, then we shall have a fan wheel, every one of these cards will represent an equipotential surface. This floor on which I stand, supposing it to be level, is such a surface as respects gravitation. It is an equipotential surface on which we can place a locomotive and set it going, and no work would be done in consequence of climbing up here or going down there. The floor above would also be an equipotential surface; but the man who attempts to go up there will of course do work in going from one place to another. Every one of the little equipotential surfaces about our wires are just exactly to each other as these floors are to each other. If we come from that card up to the next, we have to do some work, and the work is estimated in the same way as the work would be in getting from one of these floors to the other.

Now, the cases differ only in the fact that the thing which produces it in the one case is the current going through the wire, whereas in the other you have a great mass of rocks and material making up the mass of the earth. If we go from one of these earth planes to another, we do exactly the same as we would in passing from one of these planes about the wire to another, only the lines which join these planes are said to be plumb.

If a current be passing in any given direction, say thus, it is accompanied by its magnetic field consisting of circular lines of force and its radial planes, as we have seen; but the theory of Maxwell requires that the effects of any variation of the current, and so of the magnetic field, shall be propagated outward with the velocity of light, the direction of the propagation being at right angles to both the current and the lines of magnetic force, so called. Now we are very near the end of this discussion, and have reached a part which I desire that you will catch hold of. Suppose, instead of having a continuous current passing down the wire and having this magnetic pole revolve around it like this, we put in an alternating current. Then these circles are developed around the wire, but these circles are, in their tendency to carry the magnetic pole around current, reversed. When you have the current go up, you have this movement (showing); when it goes down, you have this. Now, there is not simply one of these lines wound about the wire, but another and another out as far as you please to go. The question now is how may we soonest pass from a position on one of those lines to one on another. We do it by a motion which is exactly at right angles to them as well as to direction of the producing currents, and an ether particle will vibrate in the same period as the current, and that vibration is light. (Applause.)

Now I will go back again. Hertz found in a large hall where he carried on his experiments that there were certain interference phenomena; for instance, the length and the strength of the induced spark was different from what it ought to be. He kept in mind that the adjoining side of the hall presented a large reflecting surface. If sound had been thrown on that, it would have been reflected back. If a wave of sound struck on the adjoining wall it might be thrown off and give an interference, as two sounds not differing in pitch may give you absolute silence. He found that when he moved his apparatus from one position to another with respect to the wall, he could either cause the sparks to appear or disappear according to the relative distance at which he placed them. He thus found that his waves were about nine meters long. He calculates the time occupied in one oscillation, from the wave length and the known velocity of light, and finds that it agrees fairly well with the value calculated from the capacity and inductive capacity of the circuit employed.

Now, how long are these light waves by means of which we can see? Divide your millimeter into ten million equal parts, take those as your units, write down point 588, and you have the wave length of ordinary yellow light. It is, therefore, inconceivably shorter than any distance that we are accustomed to measure, except by indirect trigonometrical processes. Now, that is something like the wave length we want to see with, but the wave you get by Hertz's method is much longer than I can reach. When we can produce alternations of current sufficiently rapid, we shall have the light we want without the production of an immense amount of heat which we do not want. Now suppose we had achieved that. A wire which is now a conductor and conveys a large amount of energy from one point to another would then convey just the form of energy we want, light would beam out from the conductor, and you might handle it without any heat being perceptible. It would simply burst out with light and be a luminous thread running through the air. That is what electrical lighting has to reach, or otherwise it will not be perfect. It is altogether likely that no conductors with which we are at present acquainted will suffice to transmit such alternations of current as we need.

Langley's experiments on the moon show it sends wave lengths greater than those which come from ice, and you have not only those, but you have all grades of vibrations up to those which are away beyond all possible means of detection except by the most refined photographic processes, and in order to get what we want—these miserable few vibrations suited to vision—we have to produce those all together. As Professor Lodge has said, it is as if a man who wished to have less than one single octave must blow the whole organ at one time. That is what we do as a matter of fact. I now suggest one or two things that look hopeful. I am not afraid of giving this away, because I do not believe any of you will get up to-morrow and accomplish it, and I do not pretend that I see my way any clearer, though I tell you frankly, I am going to experiment. Let us see what we can do. We can take an electric current and make it alternate—we can do that perfectly. We can make magnetic waves go back and forth and make the current alternate. Now, what we may try to do is to take a beam of light which has a vibration already in parallel planes and harness that to a wire, so that it will make a current vibrate and also make the magnetic field about the wire vibrate.

In other words, if you cannot do the sum, take the answer and work it backward. That is what I propose to do, and I will hint to you exactly how I propose to do it. It cannot be done with the ordinary materials employed for conductors if it has to heat the wire. The heat in the wire is most likely due to nothing else than a series of closed electric circuits in which the electric motion is around the molecular parts. We must get something that is not a conductor in the ordinary sense. I remind you that the amount of energy expended in the movement in the high vacuum tube, in the ordinary tube where you have the most beautiful illumination, is, as a matter of fact, very small, since when it is properly managed the amount of heat generated in it is very small. I point out to you next that there is one substance in which we have the properties of both the conductor and the non-conductor present, and there are some very hopeful indications in that. A selenium cell, which is semi-transparent when it is upjoined and a battery current is put through it, is found to have its resistance diminished immediately a flash of light falls on it.

The question is, Does its resistance diminish immediately, or is a force set up which conspires with the electromotive force? I do not know which it is, but something may be advanced in favor of either view. Let us see how our problem works backward. Suppose we make a polarizing apparatus by which we can polarize a long web of light. We could employ several glass plates. Let sunlight strike on this bundle at the proper angle, and the light that is reflected from it is polarized. It will consist of vibrations all sorted out in parallel planes by themselves, so that they will not be fighting at cross purposes. Now let this long polarized web of light be passed through a narrow slit so as to pass directly upon, or near, the conductor in which we wish to set up an alternating electric current. If the proper conductor can be found, it should have the current set up in it, and this should produce a magnetic field about it. If we put an alternating current through the conductor, we shall get a series of alternating magnetic circular lines of force and light waves. Therefore if we take the latter right by the horns, so to speak, and apply them as an electromotive force, we ought to be able to evoke the electrical current and the magnetic field at the same time. In other words, those three fac-

*An address before the New York Electric Club, December 20, 1888.

tors being in existence, any two of them ought to be evoked by simply giving the one. That is what ought to be brought about; whether it will be brought about with conductors or with non-conductors I do not presume to say; but it will have to be done perhaps indirectly.

The experiments of Hertz show that electrical actions can go on exactly like acoustic actions. The theory of Maxwell—and the experiments of Hertz confirm it—is that the actual wave of dynamic induction is at right angles to the lines of magnetic force and to the electrical disturbances by which they are set up. Those waves differ from light by which we see only in their lengths. They need to be shortened. What we want is an alternating current or discharge of some sort or other which shall enable us to produce the alternations with such frequency that the so-called conductors will break out and shine directly.

If we see no way of doing it at the present time, let us try to work the problem backward by taking light from the sun and polarizing it and applying that to the conductor, and so endeavor to set up in the conductor alternating disturbances which correspond with it in frequency, so as to note their effect and see if possible precisely what we have to do. A dynamometer ought to be constructed which would be capable of measuring the effect. But with the ordinary opaque conductor such frequency means confusion among the molecules, which brings about a difficulty. This is what we must get rid of.

You have been remarkably patient, and I beg you will accept my thanks for the way in which you have endured what I have said and for the courteous invitation you have given me to come here and talk. It frequently happens that one who can talk longest on a given subject knows the least about it. But I chose this subject with "set purpose and malice aforethought," not that I hoped to instruct you, but thinking that some one among you might catch an idea from my remarks and see that there were lines of experimentation which have not yet been developed and some of which I have briefly sketched. It seems a shame that we cannot have such vehicles as we choose—that we cannot get light without heat—that we cannot get the result we aim at directly without the accompaniment of so much useless waste. You are burning up tons of coal for driving machines to no purpose whatever. When is there an end to be reached? In the light of the doctrine of the correlation of forces and conservation of energy we should be able to reach the desired result with all simplicity. (Applause.)

Mr. Garratt: I wish Professor Brackett would give us his views as to the historical significance of the Hertz experiments.

Prof. Brackett: Gentlemen, it seems to me the position of affairs is about this: Before the experiment, which was almost an accidental one, by which the relation between the current and the magnet was brought about, the electricians of that age believed that they had finished with their art. They said in about so many words—the best of them—the subject of electricity is one of those things that the human mind now has got done with; there is nothing more to be done; the whole matter is closed up. Now let us see what happened. It is questioned whether it was not accidental, as much so as Galvani's original experiment. Here was a needle brought near a current. A law was found about it. Ampere took hold of it. A whole literature was created at once. Then men began to mouse around, and they found that some of these things had been reported before in a vague, indefinite way and nothing had come of them. Henry, in 1832, found that a Leyden jar when discharged gave an oscillatory discharge back and forth.

Later he published other papers in reference to it, down to as late as ten years afterward. Fedderson worked on the subject, as did several other men, and the whole matter of the oscillatory discharge was put beyond question. Now we find that at the late meeting of the British Association at Bath, men like Preece doubted very much the oscillatory character of the discharge. Thus these recent labors of Hertz really begin with Henry's experiments. Now Hertz has shown, as I have tried to bring out—I may have failed to make the impression—that the only difference between those vibrations which he produced and those which are so excessively minute as to constitute visible light, is in the length. If therefore he had identified that kind of onward propagation which we call electro-dynamic induction—if he has identified that with light, he has confirmed absolutely the theory of Clerk Maxwell, by which, starting with a few equations founded on electrical phenomena, he came out with those identical with Frenzel's founded on luminous phenomena, so that we may see the object we are trying to reach; and if having clearly obtained sight of your port is not something in trying to get there—if that is not an epoch—I fail to see what would be. I think it is epoch making when the electrician finds himself not merely putting things together and trying to bring something to pass by mere trial, but is working steadily toward a definite end in the future. From the matter having been a certain jumble, we have a definite object before us. How then can it fail to be accomplished? Now on the other hand Hertz ought not to be credited with everything. The fact is Sir William Thomson comes in here, and the very mathematical work on which Hertz relied was his.

Dr. S. S. Wheeler: I would like to ask the Professor why the increasing of the Ledyen jar decreases the time required for the discharge without the points being brought nearer together.

Prof. Brackett: The answer is simple, and Professor Henry showed the principle involved. It is due to the self-induction of the wires or the connections which run out in the sparking points. Suppose a Leyden jar charged. Now if the discharge could be made infinitely short, so that there would be no self-induction in it, we should have simply the flow from the inside to the outside, whatever that would be, and the jar would be discharged. But recall now one of Professor Henry's experiments. He states it to be in about these words: When a small battery is moderately excited and its poles are connected by a copper wire not more than a foot in length, no spark is perceived when the connection is either broken or formed; but if a wire thirty or forty feet long be used, here is a vivid spark on breaking. Now the explanation of that is this: When rupture occurs, we have the "extra spark" simply, a spark that is due to a current which is set up in the wire itself by the action of one portion of the wire upon another. The consequence of that is that the wire itself not only discharges the jar, but recharges it in the opposite direction. We have simply the action of the molecules to deal with, whereas in experiments which *we* can perform, we have to do with the action of masses. In other words, to answer the question explicitly, because the whole charging and recharging due to the extra spark in the conductor is remitted to the action of molecules, we have turned it over to nature.

In the ordinary gas flame there is no doubt a great multitude of oscillations going on among the molecules sufficiently rapid and of a kind suited to set the ether into the kind of motion which in general we call light. If we could arrange a sufficient number of Leyden jars so as to utilize all their oscillatory discharges by even distribution in time, we might be able to excite luminous waves in that way which would be short enough to serve for vision. The only question is how to arrange the jars! I will repeat my answer: Because the charging and recharging which stirs up the spark which we call light occurs very many times a second, and is due to the self-induction of the conductors, and that is to be referred to molecular activities more rapid than any device which we can get up, that works with matter in masses.

Dr. Moses: In a conversation with Professor Brackett he called attention to the fact that among the animals in nature they have already some means of carrying on this enormously rapid vibration without the production of heat waves, so that you must not think that you have mere hypothesis in the air, for nature has done it on the most beautiful scale already, and we have only therefore but to interpret nature.

Prof. Brackett: Some years ago, I had some luminous beetles, those large fellows from the West Indies. You could take one of them and hold it up and read a newspaper print without difficulty. I may say it was a good lamp, and therefore offered a very good means of studying this matter. On bringing the spectroscope to bear upon it, one kind of light only comes from it. There was a band just at the junction of the green and the yellow; just the kind of light you would want to see with. Now, on bringing the thermopile to our aid, there is no evidence that there is ever any more heat emitted from that object than there would be from any other insect of about the same size. He therefore is doing just the thing we want to do. He is making the ether wag at the proper rate, leaving all the other motions out. The problem, therefore, has been solved by nature, and it is incumbent on us to try to get its solution if we can.

[Continued from SUPPLEMENT, No. 683, page 10912.]

YEAST: ITS MORPHOLOGY AND CULTURE.*

By A. GORDON SALAMON, A.R.S.M., F.I.C., F.C.S.

LECTURE III—CONTINUED.

HAVING now determined that carbohydrates (preferably sugar), proteids, and peptones, together with mineral matter containing the elements phosphorus, potassium, magnesium, or calcium, and sulphur, constitute the essential nutritive ingredients of fungi, and *inter alia* of yeast, we are in a position to inquire for what purpose they are required, and what it is that they go to form. This can only be effected in our case by reference to the constitution of the yeast cell, because it is only those elements which are actually necessary to the formation of those constituents which will be assimilated as nutriment. Judged by this test, it is found that all the above mentioned elements are required for the production of two substances of which the yeast cell is essentially composed, cellulose and protoplasm.

Cellulose is a member of the family of carbohydrates, and has the composition $n(C_6H_{10}O_5)$. It constitutes the cell wall of all plant structure. When in a sufficiently fine state of subdivision to be examined under the microscope, it is colored blue, like starch, by a solution of iodine; it is turned black by fluoride of boron; and it is completely soluble in an ammoniacal solution of cupric hydrate. It is possessed of a remarkable power of resistance to other chemical solvents, and of extraordinary solidity and elasticity. This latter property is recognizable in the extent to which the mother cell can expand without rupture when forming an ascus to allow of reproduction by endogenous division. The yeast plant, as typifying a simple plant cell, does not depart from the usual role of having its enveloping membrane formed of cellulose; but it exhibits wide dissimilarities from the cellulose of other plants. This has been observed by De Bary, who has shown that the cellulose of fungi is not colored blue by iodine; that it does not give the characteristic reaction with Schultz's reagent, and that it is insoluble in an ammoniacal solution of cupric hydrate. For these reasons he has distinguished it by the term fungal cellulose. Richter, however, has shown that it has merely to be digested with an 8 or 10 per cent. solution of potash to be converted into normal plant cellulose possessing all its typical reactions. In this way its relationship to the more highly organized cell structure has been established.

Protoplasm is the name given to a liquid substance of slimy consistency, which is an essential component of every organized cell. It is itself endowed with a specific organization, and is capable, under conditions suitable to its activity, of exhibiting motion. It may be regarded as expressing the lowest and most elementary phase of living matter. It has been termed by Huxley the physical basis of life, and may be said to mark the boundary line between those highly complicated chemical combinations which, although able to arrange their constituent atoms about one another with reference to some order of symmetry or asymmetry, are nevertheless devoid as a system of the power of constructive increase and those equally complicated atomic combinations which are endowed with this property in virtue of the exercise of an aggregate of attributes, hitherto undifferentiated and unintelligible. These we have learnt to embody under the name of "life."

Life is unknown without the presence of protoplasm, which is to be found in every organized living cell, whether animal or vegetable. It need not necessarily fill the entire hollow space of each cell in order to exercise its functions, nor does it actually do so. This is more especially the case with elongated cells, in which the protoplasm accumulates toward the sides of the cell wall, leaving one or more unfilled spaces which are recognized as vacuoles. Yeast cells are often only partially filled with protoplasm, and in this way vacuoles are usually observable therein; in many cases there are several in one cell.

The enveloping cell membrane is generally an accompaniment to protoplasmic vitality, but it is not an indispensable one. Familiar instances are to hand in the early stages of the life history of some of the myxomycetes, or slime fungi, in which the protoplasm, although unbounded by any cell wall whatever, is nevertheless capable of expressing its vitality in terms of motion and of constructive increase. It can maintain the exhibition of these extraordinary phenomena with unimpaired energy for days together, and it is only when proceeding to the development of spores that it invests itself with a membrane, which gradually acquires the characteristics of fungal cellulose. Such is the case with the well known flowers of tan (*Æthalium septicum*). This fungus has one stage in its life history in which it exists as naked protoplasm without a cell wall—a plasmodium, as it is called—and in sultry weather, preferably in darkness, it issues forth from the tan which serves as its substratum, and when it emerges into the open it will creep up stems of plants and remain there for days together; or several plasmodia may fuse and form great flat cakes of bright yellow liquid which sometimes weigh many pounds. In the earlier phases of its growth it will re-enter the tan upon exposure to light, but later on it is not so sensitive to its influence.

This substance, so far as can be ascertained, consists solely of naked, living protoplasm. It is exceedingly doubtful, however, whether it is one body of definite composition; indeed, it may be regarded as almost certain that it is a mixture of several substances which unite to form an apparently homogeneous body capable of growth, when nourished and maintained at a suitable temperature. Although there may be several compounds entering into its composition, they probably all belong to the same class, and bear a close relationship to those bodies which Mulder has classed together under the name of proteids. They are synonymous with albuminoids, and include the albumen of blood, of egg, fibrin, casein, and the peptones. They contain about 15 per cent. of nitrogen and 1 per cent. of sulphur.

It is a matter of speculation how the protoplasm is built up, whether it is formed from proteids, or whether it is produced synthetically from other bodies. That plants have the power of constituting proteids we have already seen, and to this end they can effect the decomposition of substances containing one or more of the necessary elements. It is for this reason that sulphate of lime, or magnesia, is so easily decomposed in the progress of plant assimilation, and we may regard oxalate of lime, the crystals of which are so commonly met with in the course of fungal development, as a by-product arising from the assimilation of sulphur in proteid formation.

The manner in which the protoplasm is formed within the plant cell—*i. e.*, the form in which the elements are introduced for assimilation—will probably vary with the character of the plant. It is scarcely probable, for instance, that it will be the same in a chlorophyl plant, where the cells are characterized by their interdependence, as with fungi, where they are typified by independence. Then, again, the normal character of the food supply has to be taken into account. In a saprophytic food, such as brewers' wort, a partial decomposition has already been effected, and it seems improbable that the proteids which it contains should require to be wholly decomposed to be rebuilt into protoplasm. If, however, the latter can be formed from proteids, and if the final synthesis can be effected within the cell wall, as there is reason to believe is the case, then it follows that of all the proteids it is only the peptones that can directly take part in the formation of protoplasm, because it is they alone of all the proteids that are capable of diffusion through cellulose.

The functions of the other proteids in brewers' wort are, notwithstanding, generally apparent, because they are converted into peptones by molecular cleavage and the assimilation of water, just as starch is similarly cleft by means of diastase, and converted into sugars. In this connection it is important to draw attention to a difference existing between the assimilating powers of fungi and other plants for nitrogen. In ordinary circumstances the best vehicle for the conveyance of nitrogen to plant cells is in the form of nitrates. Hence it is that they are so largely used for manurial purposes. This is not the case with fungi, and, therefore, with yeast. They cannot assimilate them, and the nitrogen cannot be more favorably presented than as peptone. It has often been stated that the presence of large quantities of nitrates in brewing waters is prejudicial to fermentation; but while it is, perhaps, difficult to follow the reason for this statement, and notwithstanding that there is every reason to doubt its accuracy as it stands, it must be conceded that their presence cannot exert any power for good in connection with the problem of yeast nutrition.

Apart from the fact that protoplasm always contains a small amount of ash when burnt, which may or may not be present as an incorporated impurity, it is invariably found that it contains a certain amount of water, and in proportion as this is withdrawn, it loses its vitality, and at length dies. Protoplasm may therefore be regarded as some form of proteid *plus* water. Sachs regards the latter as occupying an analogous position with regard to protoplasm that water of crystallization does to crystalline bodies. Nasse and, more recently, Schutzenberger have made some interesting experiments with respect to the hydration of proteids; but hitherto they have been inconclusive.

When we have described the cellulose and protoplasm of the yeast cell, we have arrived almost at the limits of reliable information respecting its internal constitution, for although it is tolerably certain that the term protoplasm expresses an organization capable of undergoing processes analogous, at any rate, to those of assimilation, digestion, excretion, circulation, and reproduction as we know them in the more highly developed forms, still we have but few definite facts to guide us to a decision as to the manner in which those processes

* Lectures before the Society of Arts, London, 1888. From the *Journal* of the Society.

are performed. We do not know whence is derived the irritability which stimulates the protoplasm to action, and we are ignorant as to the mode of formation of compounds which have been ascertained to exist in the yeast cell, or at any rate have been separated from its interior. A few points, however, demand attention, because it seems probable that before long they will lead to explanations of at least some of the difficulties with which we are at present confronted.

By means of staining reagents, and more especially of hæmotoxylyn, or solution of logwood, it is possible, as shown by Schmitz in 1879, and later by Hansen, to differentiate from the protoplasmic contents of the yeast cell a granular nucleated mass of exceedingly minute microscopic dimensions and of varying form. It is surrounded by a watery film of proteinaceous matters, which, although resembling protoplasm, is stated to differ from it in some essential particulars. The watery fluid has been termed *nucleoplasm*, and the aggregate of granules the *nucleus*. Zacharias has found that the latter contains free phosphorus.

Recent observations indicate that more highly developed plant cells may contain many nuclei, hundreds and even thousands, but so far as is at present known the yeast cell is uninuclear. It is almost certain that the nucleus is a potent factor in fertilization and reproduction, because it is never absent from plant cells during cell formation; indeed, even with the most highly developed forms it is found that in the embryonic and growing stage the cells contain only protoplasm, nucleoplasm, and nuclei. It is probable that they are present in the cells of all fungi, more especially in asci, and it is certain that they are concerned with the formation of daughter cells, some of their functions in this direction having already been observed. Lest the ordinary granular contents of the cell should be mistaken for nuclei, it is perhaps well to add that they are most difficult of detection, and demand the search of an experienced microscopist.

Nägeli and Low, to whom we are indebted for most of the information at present available respecting the constitution of the interior of the yeast cell, have defined an interior lining to the cellulose membrane. It is very gelatinous in character, and probably exercises some definite function in connection with the cell economy, but its nature is still obscure. When this gelatinous membrane is repeatedly boiled in hot water, it constitutes a gummy mucilage, to which Nägeli and Low have given the name "yeast mucilage." It is evidently a carbohydrate, though differing in composition from cellulose—an analysis in the dry state having furnished figures aproximating to the formula

$$3(C_6H_{10}O_5+H_2O).$$

If protoplasm be regarded as a living organization, and if it be granted that it is capable of supporting it by food assimilation, it follows that it must have the power of effecting numerous reactions and decompositions in order to do so. We may regard fermentation as among the expressions of such reactions and decompositions; and it is reasonable to conclude that fermentation only takes place when the saprophytic food is in immediate contact with the protoplasm, or at any rate within the sphere of its molecular action. This is Nägeli's view, and if it be correct, it would appear probable that actual fermentation is accomplished within the cell itself. This would satisfactorily account for the fact that compounds which clearly represent stages in the gradual degradation of the saprophytic food are always recoverable from the contents of a yeast cell obtained from a fluid in which fermentation is taking place.

In addition to this, fungal cells are provided with means of storing a supply of food material assimilable in case of need, and moreover they, in common probably with all plants, secrete a compound or series of compounds which have the power of so altering the composition of plant food as to render it easily assimilable, if it be not already in that condition. These bodies have been termed soluble ferments. The term is not altogether a happy one, because the effect which they produce is so totally opposed to that of fungal ferments. They act alteratively, that is, they produce a mild and gradual change, and they may effect the addition of one or more molecules of water in pursuance of this power; but they cannot effect radical decompositions, such as the degradation of carbohydrates into alcohol and carbonic acid, and they are not imbued with vitality. Among such soluble ferments are found the diastase and peptonizing ferments of plants and the so-called invertin of saccharomyces.

The latter body is secreted by true saccharomyces, and, as is well known, has the power of inverting solutions of cane sugar into assimilable sugars, viz., lævulose and dextrose. This change must not be regarded in the light of a fermentation, but as a preliminary to it. The quantity of invertin contained in the yeast cell is so small as to be scarcely appreciable by the methods at present available for its estimation. But its power of effecting the preliminary preparation of a saprophytic food must not be judged from this standpoint, because it would appear certain that, if necessary, each cell is capable of inverting far more carbohydrate than is required for its own purposes for food. The point is not devoid of practical importance. It is often urged that yeast is weakened by the use of raw sugar in brewing, because it has to be inverted by the invertin of the yeast before it can be rendered available as a yeast food. It is claimed that the energy thereby demanded of the yeast secures its speedy deterioration. I do not for one moment urge the claims of raw sugar over well-made glucose, but this reasoning has always appeared to me to require proof, which it is impossible to adduce. On the other hand, I may say that I am acquainted with several breweries in which raw sugar is employed in small proportions without any diminution of yeast energy; indeed, I know of one in which raw sugar has been constantly used, especially in the production of black beer, and there has been no necessity for changing the yeast for upward of eight years. I must not be understood, because of this assertion, to advocate its use as an entire substitute for inverted or other more easily assimilable sugar, because I am aware of the disadvantage which may attend its employment. I would wish merely to combat the view that within the limits of practice in England, the use of raw sugar is necessarily attended by a weakening of the yeast.

Starch, which is always secreted in some of the interdependent series of phanerogamous plant cells, is scarcely ever found in fungal cells, and, so far as observation goes, never in yeast. But fat, in varying quantities, is an ingredient of constant occurrence. Its amount varies considerably with different species of fungi, but would seem to bear some ratio to the amount of oxygen needed to sustain life. Why this should be so remains to be explained, but, as a matter of fact, mucorini, which will only grow when in the presence of a free supply of oxygen abound in fat; whereas saccharomyces, which, as we shall see, require comparatively but a small amount of oxygen for development, are very deficient in fat. In the case of the higher plants the fat is demonstrably obtained only from proteids, whereas with fungi it may be formed either from proteids or directly from carbohydrates. The fat is disseminated in fungi, more especially during the vegetative period, in the form of minute globules interspersed about the protoplasm, and often causes the latter to appear granular and cloudy.

The facts to which attention has now been directed in connection with the composition of the yeast cell may be summed up by an inspection of the well known analysis of Nägeli. It may be that the results here given would vary somewhat had the culture been pure, in the sense in which Hansen interprets the term, and that they would also vary for each particular species of saccharomyces, but they will certainly suffice to allow of a general opinion being formed as to its composition. It is as follows:

	Per cent.
Cellulose and gelatinous membrane forming the cell walls	37
Proteins (*a*) Ordinary albumen	36
Proteins (*b*) Easily decomposable, of the nature of gluten casein	9
Peptone, precipitable by acetate of lead	2
Fat	5
Ash	7
Extractive matter*	4
	100

The mineral matters contained in the ash and the ultimate analysis of the cell may be expressed by the following analyses. The reservations expressed with respect to the figures of Nägeli apply with even more force to these:

	Top Yeast (Mitscherlich) Per cent.	Bottom Yeast (Mitscherlich) Per cent.
Phosphoric acid	53·9	59·4
Potash	39·8	28·3
Soda	...	....
Magnesia	6·0	8·1
Lime	1·0	4·3
	100·0	100·1

Having somewhat fully discussed the conditions necessary to the formation of a yeast food, it becomes intelligible in what manner malt wort fulfills its essential requirements. This we shall proceed to consider in the next and concluding lecture.

(To be continued.)

* Containing bodies not precipitable by acetate of lead, including a substance resembling peptone, small quantities of invertin, leucin, and glucose; still smaller quantities of glycerin, succinic acid, cholesterin, guanin, xanthin, sarcin, and probably inosite, with traces of alcohol.

DAIRY SCHOOLS AND "WORKING DAIRIES."

By J. S. WOODWARD.

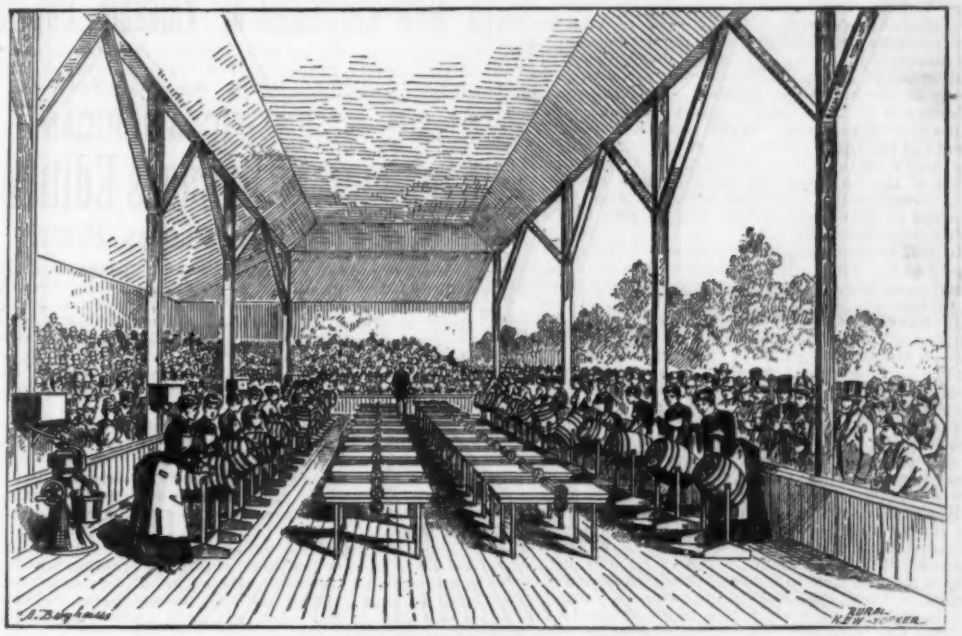
ONLY a comparatively few years ago, of all butter made, probably Danish was the worst in quality and most unattractive in form, and it found no sale outside the home market. Realizing that all the conditions of soils, climate, grasses, and water were perfectly adapted to the production of the finest butter, a few public-spirited Danes began the systematic instruction of the butter makers (mostly girls), and induced the government to make appropriations for the continuance of the work, and, although but limited sums have been expended, so much improvement has been made that now Danish butter finds ready sale in the best markets at fancy prices, and as a long-keeping butter it has no superior.

It was not long before the English noticed the change in the quality and appearance of the butter, and being quick to discern the cause, an effort was made to produce like good results by the introduction of this system of instruction into the British Islands. One of the pioneers of these dairy schools, and one of the most successful, was established in Munster, near Cork, Ireland, and a later one, that has had great influence in making these schools popular, was established at Glasnevin, near Dublin. It is mainly the success of these schools that has led to the establishment of others, both in England and Scotland. Both sexes are admitted, but mostly girls become students of butter making, and the demand for instructors and dairy managers is so great that the most efficient students find ready and constant employment.

Both of these schools owe much of their success and usefulness to Prof. Thomas Carroll, a most indefatigable worker and a persistent believer in this mode of dairy-instruction. The Royal Agricultural Society (soon followed by the Royal Dublin Society and also the next most important society, the Bath and West of England) saw the advantages of bringing practical dairy instruction to the notice of visitors by the establishment of what are called "working dairies," and so popular have these become that there is now scarcely an important agricultural show held in the United Kingdom of which a "working dairy" is not one of the leading features.

Among the most efficient workers at these demonstrations and among those oftenest called for are Prof. Thomas Carroll, Director of the Glasnevin School, Dublin, and Prof. James Long, of the Royal Agricultural College, Cirencester. Another very efficient worker is Miss Mary Connell, at present employed as instructor of butter making at the Cheshire Dairy School, and a former pupil at the Munster School, under Prof. Carroll. Last summer, while in England, I had the pleasure of attending several of these "working dairies," the most important of which was the one at the Bath and West of England show at Newport, Monmouthshire. This was in operation five days, or during the whole continuance of the show. The hours of working and instruction were daily from 9 A. M. to 6 P. M., and I can give no better idea of the management and scope of the instruction than to copy the programme of a single day:

A. M. 9 to 10. Dairy and dairy utensils open to inspection.



A BUTTER MAKING CONTEST.

A. M. 10 to 11.30. Cream separators at work by steam and hand power.

A. M. 11. Illustrations of the making of Devonshire cheese.

A. M. 11.30. Prof. Carroll lectures and Miss Connell illustrates improvements in butter making.

P. M. 12.30. Prof. Long illustrates the making of soft and foreign cheese.

P. M. 2. Butter making competition by males and females.

P. M. 5. Prof. Long's lecture.

P. M. 5.30. Dairy and utensils open for inspection.

Prof. Long's topics were—Dairy Cattle, their Feeding and Management; Milk, Cream, and Butter; Butter-making at Home and Abroad; English Cheese-making. Besides the separating of cream by mechanical means, the various modes of setting were tested, and the milk was tested both before and after the separation of the cream, so as to show which device extracted the butter most perfectly.

Prof. Carroll usually treated of butter-making, showing the right and the wrong way, and commented on the manner in which Miss Connell was handling portions of butter.

The engraving, taken from the drawing kindly made on the spot for me by Prof. Carroll, shows the general arrangement of the building. It will be seen that one side and one end were furnished with seats rising one above another, so that all could easily see and hear. The other side of the building was open, so that crowds could stand and inspect the work. In the other end of the building and back of the observer (not shown) stood the stove for heating the milk and the portable engine for furnishing steam and power, and near this end of the building and adjoining was the room in which were the creamers and cream cans. The charge for passing into the building and occupying seats was 6d. (12 cents). The illustration also shows the butter-making contest, when twenty-one dairy maids were churning. At the left, the first is Miss Connell; in the far end of the hall stands Prof. Carroll. Among the others were three Danish dairy maids in their national costumes, just brought over to show their method of manufacturing butter, and through the body of the

building are the butter workers all ready for use. The churns used were the ordinary barrel, and all were alike. The cream is mixed thoroughly and dipped out, a small quantity at a time, and placed in the different churns, so as to get the quality as nearly alike as possible, the quantity being the same. Each girl then managed the cream, churn, and butter according to her fancy, and the prizes are awarded upon the quantity, appearance, and quality of the butter, after it is salted and prepared ready for market.

The attendance at all times was large, and close attention was paid to the lecturing and work. During the contests the interest was intense. The seats were packed and an immense crowd gathered on the open side of the building; and I don't wonder at it, as a more beautiful sight I never saw. Everything was scrupulously clean. The maids were very neatly though plainly dressed, and were good-looking, bright, and intelligent, and scattered among them were the Danish maids in their peculiar costume. Notwithstanding the very large attendance, so orderly was the crowd, and so intent upon hearing what Prof. Carroll had to say were they, that the only sound that interfered with the hearing of every word was the swish, swish of the 21 churns. I am promised photographs of Prof. Carroll, Miss Connell, and of the Danish maids, which I hope to receive in due time, and I will then take pleasure in showing them to *Rural* readers, with some further notes on this system of dairy instruction.—*Rural New-Yorker.*

[NATURE.]

PROFESSOR RUDOLF JULIUS EMANUEL CLAUSIUS.

BY the death of Prof. Clausius, which occurred on August 24 last, science has lost another member of the great triumvirate—Rankine, Clausius, and Thomson—who, upon the foundation laid by the experimental work of Davy and Rumford, the theoretical suggestions of Mohr, Seguin, Mayer, and Colding (which, though resting on imperfect data and defective reasoning, were the results of real scientific insight), and the splendid experimental investigations of Joule, founded and built up the great structure known as the science of thermodynamics.

Clausius was born at Coslin, in Pomerania, on January 2, 1822. While yet at school in Berlin, he gave unmistakable evidence of the bent of his mind toward mathematics and physics, and on the completion of his university course he became Privatdocent in the University of Berlin and Instructor in Natural Philosophy at the School of Artillery. He very soon gave evidence of his power as an original worker, and some of his earliest papers—"On the Nature of those Constituents of the Atmosphere by which the Reflection of the Light within it is effected," and "On the Blue Color of the Sky, and the Morning and the Evening Red"—contributed to *Poggendorff's Annalen*, were selected for translation in the first volume of Taylor's "Scientific Memoirs."

In 1857 he was appointed Professor of Natural Philosophy at the Polytechnic School of the Helvetic Confederacy at Zurich. Here he continued his researches in various branches of physics, and among these we may mention, to give some idea of the extent and variety of his investigations, "The Influence of Pressure on the Freezing Point," "The Mechanical Equivalent of an Electric Discharge, and the Heating of the Conducting Wire which accompanies it," "Electrical Conduction in Electrolytes," and "The Effect of Temperature on Electric Conductivity." He also published some short papers on some purely mathematical questions, suggested, however, by physical problems, and some papers dealing with points of what is generally known as physical chemistry.

His attention was then directed toward the dynamical theory of gases, owing to the light which it appeared capable of throwing upon questions of thermodynamics. The dynamical or kinetic theory of gases, which has received such extensive developments at the hands of Clerk Maxwell, Boltzmann, and others, was originally suggested by J. Bernouilli about the middle of the last century; but it was Clausius who first placed it upon a secure scientific basis. In 1866 he published a most important paper "On the Determination of the Energy and Entropy of a Body" (translated in the *Philosophical Magazine*), in which the very valuable and suggestive conception of the entropy of a body was first set forth.

In 1869 he was appointed Professor of Natural Philosophy in the University of Bonn.

Among more recent papers of great importance we may mention the following, all of which have been translated in the *Philosophical Magazine*: "On a New Fundamental Law of Electrodynamics;" "On the Behavior of Carbonic Acid in Relation to Pressure, Volume, and Temperature;" "On the Theoretic Determination of Vapor Pressure and the Volumes of Vapor and Liquid;" "On the Different Systems of Measures for Electric and Magnetic Quantities;" "On the Employment of the Electrodynamic Potential for the Determination of the Ponderomotive and Electromotive Forces;" "On the Theory of Dynamo-electrical Machines;" and "On the Theory of the Transmission of Power by Dynamo-electrical Machines."

When we consider the far-reaching and fundamental character of these and many other investigations, and the very wide field which they cover, we cannot but wonder at the marvelous energy of the great physicist who has passed from among us. The Royal Society catalogue contains a list of no less than seventy-seven papers published up to 1873, and those published subsequently bring the total number up to considerably over a hundred.

In addition to these, there is his great treatise on "The Mechanical Theory of Heat," of which the first volume was published in 1864, and a smaller work, "On the Potential Function and the Potential."

It would be impossible to discuss in detail the portions of thermodynamics specially worked out by Clausius, as his work is throughout closely interwoven with that of Rankine and Thomson, but it will be of interest to quote the following from Prof. Rankine, who, in his paper "On the Economy of Heat in Expansive Machines,"* says:

"Carnot was the first to assert the law *that the ratio of the maximum mechanical effect to the whole heat expended in an expansive machine is a function solely of the two temperatures at which the heat is respectively received and emitted, and is independent of the nature of the working substance.* But his investigations, not being based on the principle of the dynamical convertibility of heat, involve the fallacy that power can be produced out of nothing.

"The merit of combining Carnot's *law*, as it is termed, with that of the convertibility of heat and power, belongs to Mr. Clausius and Prof. William Thomson; and in the shape into which they have brought it, it may be stated thus: *The maximum proportion of heat converted into expansive power by any machine is a function solely of the temperatures at which heat is received and emitted by the working substance, which function for each pair of temperatures is the same for all substances in nature.*"

None will regret the loss of Prof. Clausius more keenly than the students of the University of Bonn, where he formed a center of attraction, not only as a great investigator, but as a teacher of almost unrivaled ability. The secret of his powers as a teacher may easily be guessed from the study of his published papers and treatises. Their great characteristic is the direct insight which they give into the very heart of the physical principles under discussion. The author, while showing himself a master of mathematical methods, ever keeps the physical meaning of the symbols before the eye of the reader, and never allows his analysis to carry him away into the regions of mere mathematical ingenuity. In this he was a worthy compeer of some of our own great mathematical physicists, like Thomson and Maxwell, and the greater part of his work has the additional advantage, for the majority of students, of being effected by the aid of comparatively simple analysis.

In 1868, Prof. Clausius was elected a Foreign Member of the Royal Society, and in 1879 he was presented with the Copley medal, the highest distinction at the disposal of the Society. He was decorated with various civil Prussian and Bavarian orders; and after the Franco-German war, during which he had volunteered to serve as caretaker of the wounded, he received the German decoration of the iron cross and the French decoration of the legion of honor.

G. W. DE TUNZELMANN.

* Rankine's "Miscellaneous Scientific Papers," p. 300.

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